SANTA CLARA VALLEY WATER DISTRICT

WATERWAYS PLANNING STUDY

GENERAL REPORT

CHAPTERS 1 – 7

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SANTA CLARA VALLEY WATER DISTRICT

WATERWAYS PLANNING STUDY

GENERAL REPORT AND REFERENCE

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Others who have contributed to this report are Shaikh Buksh and Val Miller.

PREFACE

The idea of a Waterways Planning Study was conceived in 1978 as a positive response to the loss of tax revenues after Proposition 13. The objectives as originally defined in 1978 were:

1. Develop a Districtwide master plan for flood damage reduction and stream management.

2. Develop a comprehensive description of waterway problems.

3. Identify low cost, high benefit projects to be constructed by the District, including projects where the assessment district approach is a possible source of funding.

4. Identify areas in which the nonstructural floodplain management approach can best be applied.

5. Identify projects which can be implemented through Federal programs or other agency programs.

6. Identify projects which should be constructed as part of land development projects (drainage fee approach or construction by developers).

7. Develop maintenance guidelines and standards to optimize flow capacities.

8. Develop comprehensive flood emergency operation plans.

The study was to be conducted in four stages as outlined below. Cost in 1978 was $264,000 per zone.

First Stage - Study Organization (Districtwide)

Organize the study, define specific guidelines and products, collect base data.

Estimated cost:	$ 24,000/Zone

Second Stage - Problem Definition (Zone-wide)

Define waterway related problems in each zone.

Estimated cost:	$ 65,000/Zone

Third Stage - Interim Results (Zone-wide)

Identify short-term objectives such as projects qualified for Federal assistance.

Estimated cost:	$ 75,000/Zone

Fourth Stage - Master Plan (Zone-wide)

Complete master plan, develop implementation strategy, prepare final report. Identify from a conceptual standpoint which flood damage reduction measures are most suitable for each reach of stream.

Estimated cost:	$ 100,000/Zone
	$ 264,000/Zone

Study products were to be a series of overlay maps and zone reports which would function similar to the District's "Master Plan for In-County Water Distribution Facilities". The study was to be a traditional master planning approach in conduct and in products.

In the course of the study it became apparent that the original objectives were too narrow and did not relate well to a comprehensive management plan. The 1978 objectives were incorporated into the broader context of the 1983 study objectives outlined below.

1983 Waterways Planning Study Objectives

(1978) Objectives are Underlined

1. Develop a Districtwide plan for flood damage reduction and stream management.

2. Develop a comprehensive data base that is easily maintained and updated. This data base will include:

   a. Conditions and problems on each reach of each stream in the five flood control zones (flooding, erosion, etc.)

b. A comprehensive description of all alternative solutions to these problems (ELEMENTS) (Includes flood emergency operation plan)

c. A description of FUNDING sources that might provide money to fund problem solutions

d. Maintenance guidelines and standards

3. Develop a system which uses the above data to quickly select solutions and funding sources suitable to address identified problems. This system must be flexible enough to respond quickly to changes that occur in the future.

Includes:

a. Projects where assessment districts are possible

b. Projects where nonstructural floodplain management are possible

c. Projects where Federal funds are possible

d. Projects where developers could implement

4. Develop a 10-year project schedule and management plan to solve the worst of the identified problems.

5. Develop a system capable of measuring progress towards meeting the District's goals.

It also became obvious that the traditional master planning approach was not going to produce all that was needed or desired. All the information collected needed to be stored where it was readily retrievable. It was also important that the information be current and the master plan not become out-of-date such that another extensive effort would be required. The 1983 study is, therefore, computer oriented, as opposed to the 1978 plan which had little or no computer application. The four stage study plan evolved into:

First Stage - Study Organization

1. Organizing and outlining the study
2. Defining specific guidelines and products

3. Research methodologies and procedures and write computer programs for:
    a. Estimating flood damages
    b. Evaluating erosion problems
    c. Estimating sediment generation
    d. Identifying and evaluating environmental setting and constraints
    e. Defining maintenance program guidelines
    f. Utilizing the HEC-2 information from the flood insurance studies.

4. Research all ELEMENTS of a flood damage reduction program and describe them including advantages, disadvantages and tests for feasibility.

5. Research all possible FUNDING sources and describe them including advantages, disadvantages and tests for feasibility.

6. Write computer program to assess creek problems and test for feasibility of an ELEMENT and FUNDING source.

Second Stage - Problem Definition

1. Collect data necessary to define creek problems such as:
    a. Flood maps
    b. Land use in floodplain
    c. Water surface profiles
    d. Soil type
    e. Environmental setting data
2. Code data and run computer programs to assess problems.

Third Stage - Alternative Evaluation

Run computer program which defines solution ELEMENTS and FUNDING options.

Fourth Stage - Master Plan

1. Write master plan report
2. Prepare 10-year planning and construction schedule

The 1983 WPS is broader in scope and more specific in its application. All the data collected in the study is referenced to the stationing established in the flood insurance studies. Therefore all analyses can be performed on any length reach or creek as desired. This is very important, for example, when defining guidelines for maintenance of a specific reach. The 1978 plan was based on predetermined reach limits. The 1983 WPS is computer oriented as opposed to the 1978 plan which had little or no computer application. The best way to store, analyze and update the data collected during the study is through utilization of the computer. This provides the greatest flexibility and time savings and insures that a master plan will be current.

The 1978 WPS was limited to the preparation of one final report for each zone. The 1983 WPS produces the same final report but also has the capability to quickly reanalyze or answer questions on the plan. It can also provide a wealth of information on District facilities which is used on daily basis.

The cost of the Waterways Planning Study for each zone was originally estimated to be:

	Stage I	Stage II	Stage III	Stage IV	Total
Cost	$24,000	$65,000	$75,000	$100,000	$264,000
Time	6 months	6 months	6 months	12 months	30 months

The cost to date and the anticipated costs to complete the study are:

	Stage I	Stage II	Stage III	Stage IV	Total
East Zone					
Actual Cost	$30,000	$111,000	$14,000	$14,000	
Anticipated Cost	5,000	5,000	11,000	25,000	
	$35,000	$116,000	$25,000	$25,000	$201,000
NW, NC, C Zones					
Actual Cost/Zone	$30,000	$14,000			
Anticipated Cost /Zone	15,000	22,000	$25,000	$25,000	
	$35,000	$36,000	$25,000	$25,000	$121,000

CHAPTER 1
INTRODUCTION

The purpose of this report is to discuss the objectives and benefits of the Waterways Planning Study and to summarize the organization and methodology that is used in the study.

The Santa Clara Valley Water District is responsible for providing effective flood damage reduction and stream management for the County. Social and economic changes such as the passage of tax reduction initiatives and environmental laws have made it increasingly challenging for the District to meet this responsibility.

In providing flood protection and stream management within the community, the District must continue to insure that maximum results are achieved with the resources available. The District must strive (a) to prevent the development of new flood and erosion problem areas; (b) to preserve and protect the natural characteristics of streams in Santa Clara County and (c) to generate revenue from alternative sources to accomplish flood damage reduction projects. This requires a well-planned and well-managed program. For this purpose, the District has designed the Flood Damage Reduction and Stream Management Program. Table 1 contains a set of goals and objectives for such a program.

While these same goals and objectives have served to guide the District's flood control program in past years, the new program will to meet these goals through a more thorough zone-wide approach, rather than the case-by-case approach of past years. The key operational elements of the program are a comprehensive assessment and inventory of the problems to be solved and development of conceptual solutions to these problems. With knowledge of the most effective solutions a strategy can be developed for accomplishing the maximum amount of flood damage reduction.

To develop a comprehensive Flood Damage Reduction and Stream Management Program, the District initiated the Waterways Planning Study.

TABLE 1

GOALS AND OBJECTIVES
OF THE
FLOOD DAMAGE REDUCTION AND STREAM MANAGEMENT PROGRAM

Goals

Provide effective flood damage reduction and stream management and coordinate all other community water-related programs to achieve full water resource management.

Objectives

General

Consider the community desires in all District programs and projects.

Perform in an efficient and effective manner within the District organization, with the community and with other governmental units.

Protect and enhance the environment in the formulation and execution of District programs and projects.

Protect and enhance the economic well-being of the community in the formulation and execution of District programs and projects.

Provide for and encourage compatible multipurpose use of District facilities.

Preserve and protect watersheds.

Flood Damage Reduction and Stream Management

Formulate and implement flood damage reduction projects and programs which provide benefits comparable to costs and which address areas of greatest potential damage first.

Provide for flood damage reduction by the use of non-structural floodplain management measures wherever feasible.

Encourage and assist in land use planning which ensures that changes in land use do not increase flood damages on-site or off-site.

Reduce stream-related hazards to the public health and safety.

Provide flood damage reduction projects and programs which minimize the expenditure of public funds consistent with other social and environmental objectives.

Manage the District's streams to ensure a desirable water quality, to protect and enhance groundwater recharge capabilities, to protect the scenic value of the natural stream corridor, to protect the riparian habitat for fish and wildlife, and to protect cultural resources.

OBJECTIVES AND BENEFITS OF THE WATERWAYS PLANNING STUDY

Objectives

The District is engaged in the Waterways Planning Study in order to develop a Flood Damage Reduction and Stream Management Program. To achieve this objective the Waterways Planning Study must satisfy the objectives presented in Table 2:

TABLE 2

OBJECTIVES OF WATERWAYS PLANNING STUDY

- Develop a comprehensive data base that is easily maintained and updated. This data base will include:

  Conditions and problems on each stream in the five flood control zones of the District.

  A comprehensive list of all alternative solutions to these problems.

  A list of funding sources that might provide money to fund problem solutions.

- Develop a system which uses the above data to quickly select solutions and funding sources suitable to address identified problems. This system must be flexible enough to respond quickly to changes that occur in the future.
- Develop a 10-year project schedule and management plan to solve the worst of the identified problems.
- Develop a system and procedures capable of measuring progress towards meeting the District's goals.
- Implement the plan.

The Waterways Planning Study enables, the District to prepare long-range plans for providing the most cost effective flood protection based upon a detailed examination of conditions in all the streams in the five flood control zones. The computer application of the Waterway Management Model (WWMM) permits the District to update this plan quickly to reflect changes in the data base and constraints under which the District operates and to measure the District's progress in meeting the objectives in Table 1.

The process of carrying out the Waterways Planning Study has been designed to be cost effective and to result in a product that will continue to be useful in the future. To insure that the District receives the maximum return on its investment of time and money in this study, the amount of basic data used in the study is held to a minimum. If data cannot serve several purposes, consideration has been given to not using it. Development of new data has been kept to a minimum. Long term use of the program for proper problem identification, project staging and program coordination will require continuous effort to maintain up-to-date accurate information and proper analytical tools. The computerized data management system (Waterway Management Model, WWMM) that developed as part of the Waterways Planning Study will make this process feasible and quick and easy to accomplish. The study makes extensive use of the computer for storage, access to information and analysis.

Benefits

The final products of the waterways planning study go far beyond satisfying the original limited objectives. The written report is a wealth of information on general planning and specific methodologies. It is also a handy reference for various federal, state, and local programs and policies.

The study assembled a vast and easily accessible data base of information pertinent to problems and facilities within the District. The data base is structured for maximum utility, easy updating and flexibility in the future. The study also developed the Waterways Management Model necessary to analyze and coordinate the data to provide appropriate information for decision makers. All work, theory and procedures have been thoroughly documented.

The Waterways Planning Study provides the tools and information for a comprehensive flood management program including:

1. A description of all ELEMENTS of a flood damage reduction program with the advantages and disadvantages.

2. A description of all Federal, State and local funds or programs which are or could be used for flood damage reduction projects.

3. A systematic, objective decision matrix which can identify feasible ELEMENTS and possible funding sources on any creek or reach of creek.

The Waterways Planning Study provides the computer model needed for long-range master planning to:

1. Estimate the flood damage potential for all District facilities.
2. Estimate the cost of solving flooding and erosion problems.
3. Analyze and prioritize entire creeks or short reaches.
4. Project a ten-year schedule for planning, design and construction based on project costs and anticipated revenues.
5. Measures progress toward flood damage reduction.
6. Identify those reaches of creeks located in undeveloped areas which are suitable for preventive (non-structural) flood damage reduction approaches. Where preventive measures can be implemented, significant cost for future remedial needs can be avoided and the streams can be preserved in their natural state.
7. Identify critical problem areas to receive greatest return on available funds.
8. Identify flood emergency programs that could significantly reduce damages during future flood events.
9. Assess the effect of flood control projects on downstream flooding potential.

The Waterways Planning Study will expedite specific project studies and ordinance review by:

1. Preparing, from the master data base, a complete and detailed analysis of flood damages in a specific area. Includes the number and type of structures flooded, direct and indirect damages for the one percent event and an estimate of average annual damages.

2. Preparing a preliminary screening of alternatives such as acquisition, floodproofing or zoning.

3. Identifying multipurpose use of facilities, potential recreational uses and the environmental setting.

4. Providing information on water surface, velocity, flows, and x-sections.

The Waterways Planning Study provides the tools and information for a comprehensive facilities maintenance program including:

1. A computer model which prepares reach by reach descriptions of the facility's design condition and acceptable maintenance condition.

2. An estimate of the cost of maintenance; where additional maintenance will have flood damage reduction benefits, and where less maintenance will save money but will not affect the flood carrying capability.

3. Identifying areas of potential conflict with policies of the State Fish and Game Department and other permitting agencies.

The Waterways Planning Study provides the tools and information to identify quickly and accurately what facilities may be affected by such program changes as FIA's interim levee policy.

The Waterways Planning Study identifies areas where non-District funds may be available for construction of facilities such as:

1. Projects which cost less than $4M are good candidates for Corps 205 projects. District funds could be spent elsewhere.

2. City cost-sharing on bridge replacement.

3. Undeveloped areas where facilities could be constructed by the developers.

4. The Waterways Planning Study will also identify areas where alternative funding sources are not a possibility. This will eliminate waste of time and money where inappropriate action may be taken, such as asking the Corps to invesigate Coyote Creek when the B/C is only .2.

The Waterways Planning Study (and Waterways Management Model) has been performing important functions even before its completion. The structure of the study and model allows separate elements to function independently so each can be fully utilized even without the eventual connection to the other elements. The WWMM has already; (1) assisted in preparation of planning studies by identifying and quantifying the problems, (2) estimated costs of alternative solutions such as flood insurance, (3) provided information for regulating a new blanket permit with Fish and Game, and (4) provided information on facilities to Design Division, Design Coordination Division and Flood Emergency Center.

STUDY ORGANIZATION

The Waterways Planning Study has been organized into the four stages shown in Figure 1. The first stage was accomplished for the five zones together and consists of five products:

1. A set of criteria, methodologies and guidelines to be used to identify and assess flood, erosion and sediment problems reach by reach (called the "INVENTORY").

2. A complete list of all possible solutions to flood, erosion, sediment, environmental quality and maintenance problems (called the "ELEMENTS" of the Flood Damage Reduction and Stream Management Program).

3. A complete list of all possible funding sources that the District could use to implement the ELEMENTS (called "FUNDING" sources).

4. A system (a set of computer programs) that uses the above data to define problems and identify the appropriate solutions and funding sources for further study.

5. A system that will set priorities on the various proposed problem solutions and develop a long-range implementation schedule.

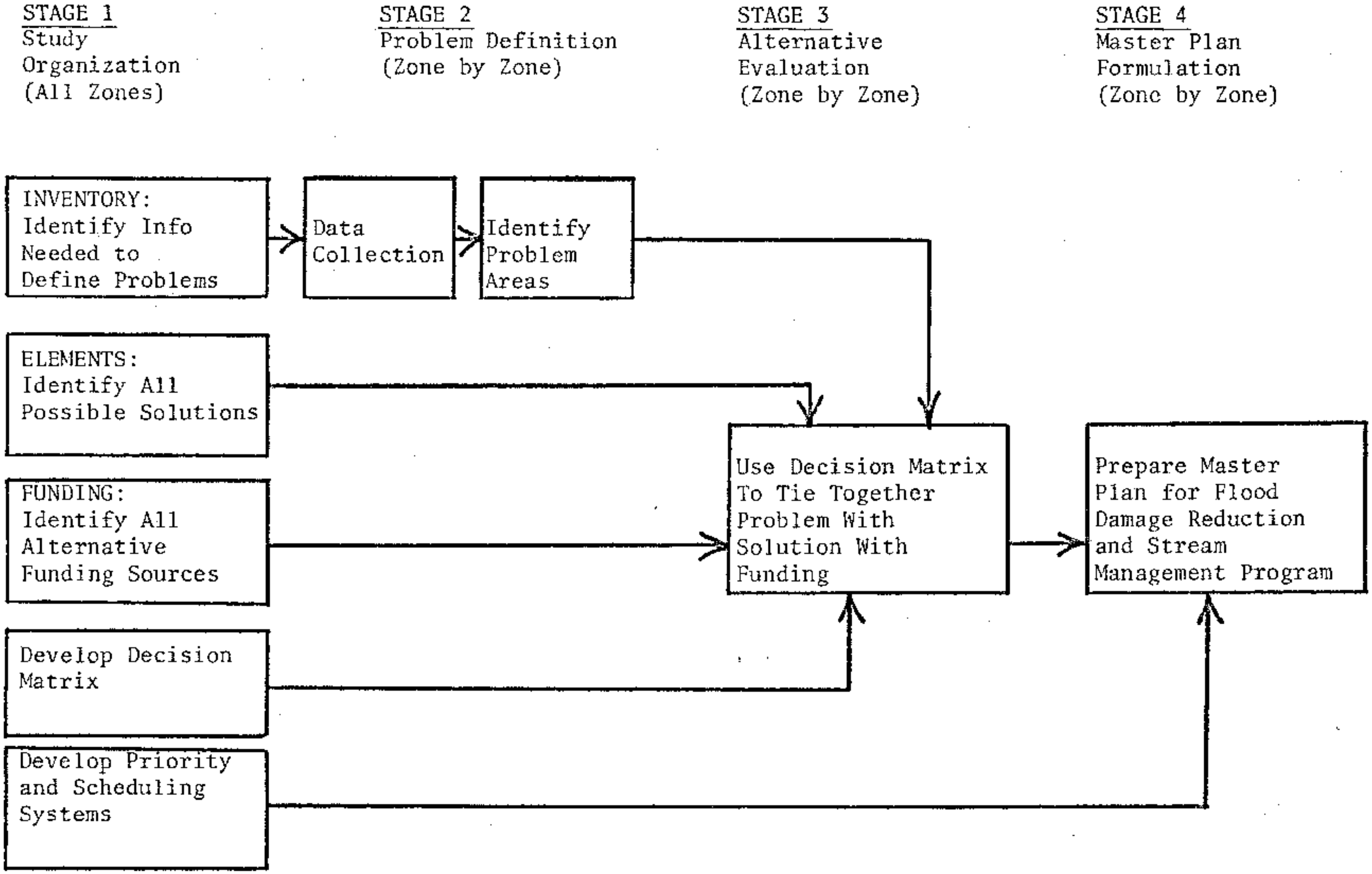
Development of these products has been completed and is summarized in the next section of this report. These products are the tools that are needed to complete Stages Two, Three, and Four. Stages Two and Three, shown in Figure 1, are data collection, problem identification and selection of the most feasible problem solutions and funding sources for further study. This process will be done for every reach of every creek within the District's five flood control zones. The result will be a table, stored on the computer, that contains for each reach of every creek in the County, the problems and the solutions and funding sources for further analysis. This data will be grouped by flood control zone for ease of use.

Stage Four takes place on a zone-by-zone basis. The data on solutions and funding sources that are appropriate for each reach of a creek are examined to identify reaches or groups of consecutive reaches upon which projects can be done to solve the problems.

These projects are identified, assigned a priority and fitted into a long-range implementation schedule.

Figure 1

Four Stages of Waterways Planning Study



METHODOLOGY

Three products of the Stage 1 study are the INVENTORY, the ELEMENTS, and the FUNDING. This section summarizes the information included in each product area and, if appropriate, describes how the data is developed.

The "INVENTORY"

The INVENTORY of the Waterways Planning Study is a compilation for each Zone of the physical and environmental characteristics of each reach of each stream in a Zone downstream of the District's "Limit of Jurisdiction". The "Limit of Jurisdiction" is the point on a stream where the area drained by the stream becomes less than 320 acres. The INVENTORY also includes an identification of the location and magnitude of all problems for which the District is responsible. The information included in the INVENTORY is broken down into the following categories:

- Flooding problems, including damages
- Channel physical characteristics
- Erosion problems
- Sedimentation problems
- Channel environmental characteristics, including groundwater recharge and recreational uses
- Maintenance needs

The purpose of the following discussion is to outline for the categories shown above the data needed for the INVENTORY and where it can be obtained.

Flooding/Flood Damages

The information needed to calculate the value of flood damages includes the extent and depth of flooding, land uses and market values of property in the area flooded and a formula to relate depth of flooding to damages. The specific data used and its sources are presented in Table 3.

TABLE 3

DATA NEEDED TO ESTIMATE FLOOD DAMAGES

Data	Source
Area Flooded	Maps developed by George S. Nolte & Associates for the Federal Insurance Administration in 1978, 1" = 500'.
Depth of Flooding	Nolte FIA maps in conjunction with USGS 1" = 2,000' quad sheets
Land Uses in Area Flooded	"Land Use Map of the Santa Clara Valley, California, July 1976 San Jose State Univ., Dept of Geology, CARTREMS Lab
Market Value of Land and Structures Flooded	Survey by District staff of property in areas flooded
Relationship between Depth of Flooding and Damage	Curves generated from data from the U.S. Corps of Engineers, SRI and others

Channel Physical and Flow Characteristics

Information on channel physical and flow characteristics is needed to enable development of other parts of INVENTORY such as erosion problems and maintenance needs. The data is obtained from: the District's Design Flood Flows Manual by A. Saah, studies by Nolte & Associates for FIA, Soils of Santa Clara by the Soil Conservation Service and surveys by District staff. The data collected are stored by the computer on two disk files and listed in Table 4. The format of these files is presented in Chapter 10.

TABLE 4

PHYSICAL AND FLOW CHARACTERISTICS OF CHANNEL
AT DOWNSTREAM END OF REACH OF CREEK

Data	Source
Channel type	Field surveys, data from previous District reports and as-built construction drawings
Bottom width	
Right and left side slopes	
Top width	
Invert elevation	
Minimum bank elevation	
Observed erosion	
Existing Manning's roughness coefficient "n"*	
Existing channel capacity*	
Soil type	"Soils of Santa Clara County" Soil Conservation Service
D_{75} and D_{50} soil particle size (mm)	
Soil plasticity index	
Drainage of area upstream of a given station	District Design Flood Flow Manual
Design 1% flow	
Design 10% flow	
Existing 1% flow	Nolte's study for FIA

* Also some data from FIA studies

Erosion

Erosion problem areas have been identified using two analytical methods, the Allowable Velocity Method and Tractive Force Method, and by field inspection. The severity of erosion problems were categorized using the definitions in Table 5. These definitions have been developed to standardize the evaluation of erosion problem areas and simplify applying priorities to them. Where field observations indicated a stable channel, the possibility of erosion occurring under more extreme events was analyzed with the Allowable Velocity Method and the Tractive Force Method.

TABLE 5

DEFINITIONS FOR CLASSIFYING EROSION PROBLEMS

1.0	Stable	There is no physical evidence of erosion problems and tractive force analysis indicates permissible velocities are greater than actual velocities.
2.0	Potential	Bank appears stable but tractive force analysis indicates potentially erosive velocities.
3.1	Active (Negligible)	Less than 3 inches of soil has eroded from bank channel practically in as-built condition.
3.2	Active (Slight)	Between 3 and 12 inches of soil has eroded from bank.
3.3	Active (Moderate)	Between 1 and 3 feet of soil has eroded from bank.
3.4	Active (Severe)	More than 3 feet of soil has eroded from bank.
4.0	Urgent	Bank is actively eroding away and poses an immediate threat to structure or threatens consequences such as total levee failure or drop structure failure or threatens the disruption of public roadway or operations of public utilities.

Sedimentation

Three methods for calculating sediment yield were evaluated. Of the three, only a method developed by Henry Anderson of the Forest Service, U. S. Department of Agriculture in 1949 did not require development of large amounts of new data. For this reason and because it seems to produce relatively good results, Anderson's method is used. According to Anderson's equation, the annual volume of sediment, called the sedimentation yield, which could be collected at a station in the channel is a function of:

a) the ratio of area of the channel upstream of the station to the drainage area upstream of the station;

b) the ratio of the annual peak flowrate past that station to the drainage area;

c) the percent of ground which is protected from erosion by vegetation;

d) a "constant" which varies with geology and soil type.

The value of the "constant" and the percent ground cover were adjusted to make predicted yields approximate observed yields.

Environment

Part of the INVENTORY is a determination of the environmental conditions in each reach of the stream. Based on the presence of individual plant species, each reach of stream has been classified into one or more of the following habitat categories: freshwater marsh, salt/brackish marsh, grassland, oak woodland, and riparian. The environmental conditions have been further specified by indices that reflect (a) the relative abundance of vegetation and (b) the overall habitat quality of the area. For example, habitat quality has been rated using the numerical and descriptive rankings shown in Table 6. This survey was conducted by the District's staff environmentalist and by Harvey and Stanley Associates, an environmental consulting firm. If the specific reach of stream is suitable for groundwater recharge operations or has potential recreational uses, such information has been included in the environmental data.

TABLE 6

NUMBER AND DESCRIPTIVE RANKINGS OF HABITAT QUALITY

Numerical Ranking	1	2	3	4	5
Descriptive Ranking	Very Low	Low	Moderate	Good	High

Maintenance

For the purposes of this section "maintenance" is defined as the program of routinely removing debris, sediment and plant life from the channel to insure that the channel can carry high flows. Maintenance of channels actually includes much more than this, such as erosion repair work, rodent and weed control, and fence repair. However, a major consideration in choosing the standard to which a stream channel should be maintained is hydraulic efficiency, or the ability of a channel to convey water given a certain level of sediment deposition and vegetative growth. If hydraulic efficiency was the District's only concern, a case could be made that, to use available maintenance funds the most productively, a stream channel should not be cleaned until the channel capacity of a reach of creek has been reduced to a point close to the expected one percent flow in that reach.

All reaches of streams have been analyzed to determine the channel capacity and freeboard for Manning's roughness coefficients ("n") and sediment depths ranging from conditions occurring in a freshly-maintained channel to those occurring with various levels of deterioration. For a newly cleaned channel the adopted Manning's roughness coefficients are given in Table 7.

TABLE 7

MANNING'S ROUGHNESS COEFFICIENT, "n", FOR NEWLY CLEANED CHANNELS FOR VARIOUS LINING MATERIALS

Channel Lining Material	Roughness Coefficient
Concrete	0.013
Sacked Concrete	0.025
Earth-lined, complete gabion lining modified and unmodified floodplain	0.030
Rock-lined and gabion lining on sides only	0.035

A decrease in channel capacity and freeboard has been calculated assuming that channel roughness increases each year and sediment is deposited at a rate equal to the annual average depth of sediment, as calculated in the sediment portion of the INVENTORY. The maximum interval, based on hydraulic efficiency alone, between maintenance activity on the creek would be the time it takes the channel freeboard to decrease to a specified minimum.

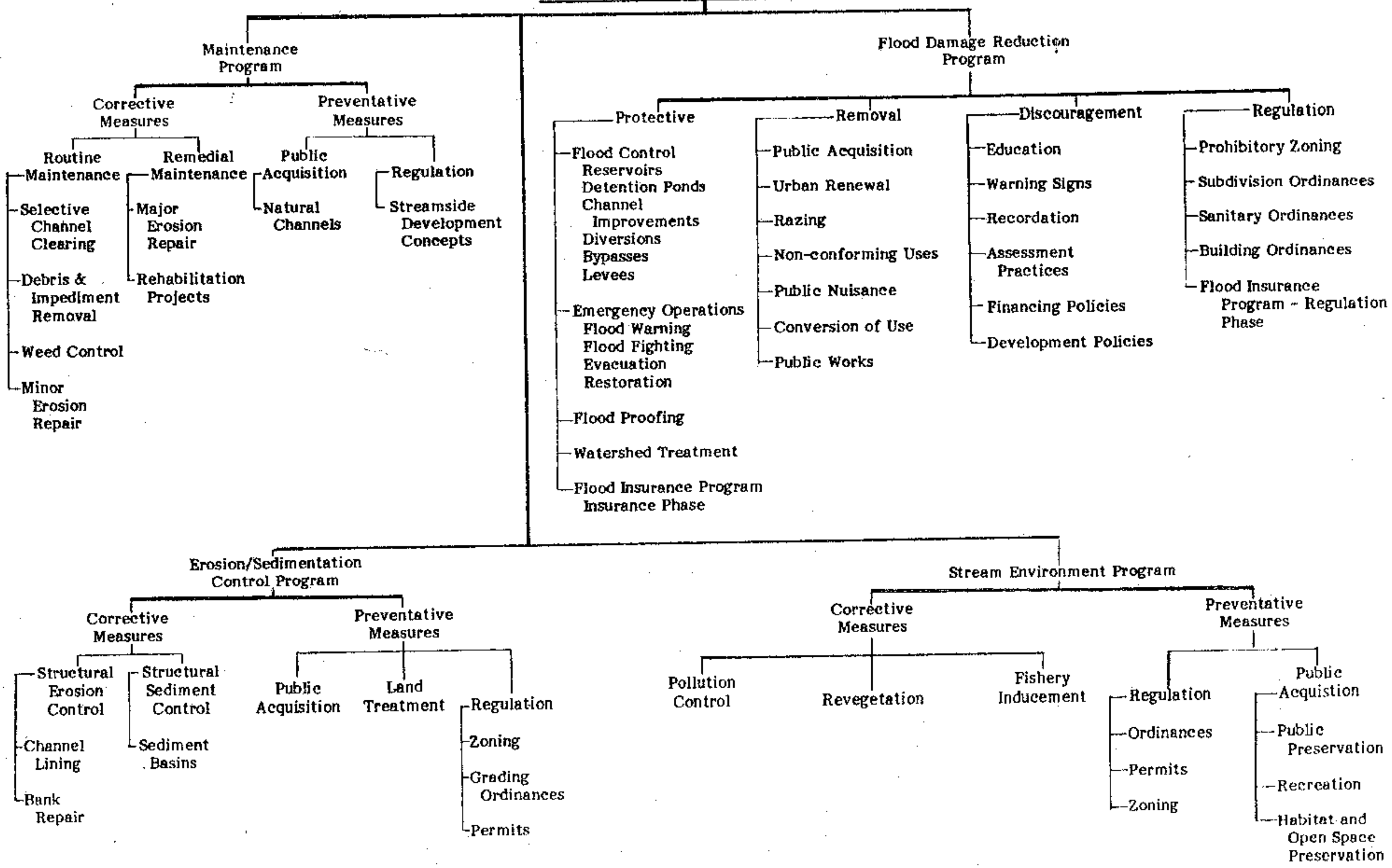
The Waterways Planning Study also will include a determination of the benefit of the most intensive maintenance possible. The maximum possible channel capacity and minimum frequency of flooding were calculated. Then, the average annual flood damage reduction benefits associated with the most intensive maintenance conditions (minimum "n" value and no sediment depth) are calculated. By analyzing benefits obtainable through maximum-interval maintenance and comparing with benefits obtainable through minimum-interval (i.e., intensive) maintenance, a judgment can be made regarding optimization of available maintenance program resources.

THE "ELEMENTS"

The District has the responsibility to solve as many of the problems identified in the INVENTORY as possible. This responsibility is met by some form of "Flood Damage Reduction and Stream Management Program" (FDRSM Program). A complete FDRSM program has the elements shown in Figure 2. Chapter 7 provides a discussion of each of these elements including its advantages and disadvantages.

Figure 2

ELEMENTS OF FLOOD DAMAGE REDUCTION AND STREAM MANAGEMENT PROGRAM



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FUNDING

There are many sources of funds which the District can attempt to use to fund implementation of the various ELEMENTS of the FDRSM Program. These sources can be classified in seven categories.

- Emergency relief funds
- Non-emergency direct federal funds
- Culvert repair funds
- Funds for rehabilitation of developed areas
- Funds for parks and recreation
- Funds for undeveloped areas
- Local funds

Table 8 contains a list of specific funding sources in each class.

TABLE 8

FUNDING SOURCES FOR FLOOD DAMAGE REDUCTION AND STREAM MANAGEMENT PROJECTS BY CATEGORY

Category	Funding Source
Emergency Response Funds	State Natural Disaster Assistance
	Federal Disaster Assistance
	Emergency Watershed Protection
	Emergency Bank Protection
	DWR Flood Fighting, Sec. 128
	Rehabilitation of Flood Control Works
	Protection, Clearing and Straightening of Channels
	State Disaster Preparedness Grants
Federal Non-Emergency Project Funds	Small Watershed Grants
	Small Flood Control Projects
	Large Flood Control Projects
	Snagging and Clearing for Flood Control
	Small Navigation Project
	Small BUREC Project
	State Reimbursement of Local Share of Federal Projects
Funds for Culvert Enlargements	City and County Capital Improvements
	Federal Aid Highway Program
Funds for Rehabilitation of Developed Areas	Community Redevelopment
	Community Development Block Grants
	Economic Development Administration Grants and Loans
	Economic Development Grants
Parks & Recreation Funds	Land and Water Conservation Program
	Urban Parks & Recreation Recovery Program
	Disposal of Surplus Federal Real Property
Funds for Undeveloped Areas	Developer Constructed Facilities
	Drainage Fees
	Special Benefit Zones
	Resource Conservation & Development Grants
	Industrial Development Grants
Local Funds	Ad Valorum Taxes
	Benefit Assessment
	Special Assessment Proceedings

PRIORITY RANKING AND SCHEDULING SYSTEM

Stage 4 of the Waterways Planning Study involves formulating a Master Plan for the Flood Damage Reduction and Stream Management Program. This product is achieved using a priority ranking and project scheduling program, applied to each zone. First the projects identified using the decision matrix in Stage 3 are assigned a priority according to criteria developed by the Zone Advisory Committees and the District. Table 9 contains the final priority ranking criteria used. Then, the stages of each project are scheduled. Each project is typically broken down into three development stages: 1) project planning, 2) design, and 3) construction. Given the list of projects with assigned priorities and budget constraints, a ten-year schedule is produced.

TABLE 9

FINAL PRIORITY RANKING CRITERIA

Priority Ranking	Weighting Factor	
1	50	Reduce flood damages - $ value of average annual flood damages.
2	12.6	Protect developed areas - total acres of developed land subject to flooding.
3	9.2	Construct reaches between previously improved reaches - Is inadequate reach between completed reaches? Yes No
4	6.3	Rehabilitate previously constructed facilities - a previously constructed facility does not provide adequate protection due to subsidence, erosion, flow rate change, etc. Yes No
5	6.1	Protect areas of proposed development - total acres of vacant land subject to flooding which is proposed to be developed in future according to city plans (Urban Service Area).
6	5.9	Protect downstream costs - cost of maintaining existing channel per mile of reach.
7	5.9	Reduce maintenance costs - cost of maintaining existing channel per mile of reach.
8	4.0	Encourage multi-purpose uses - acres of land or miles of creek which are used or will be used jointly for recreation, groundwater recharge, etc.

DATA MANIPULATION

The Waterways Planning Study is implemented using the Waterways Management Model (WWMM) a system of computer programs and computer data files. The WWMM was developed to produce the Master Plan for the Flood Damage Reduction and Stream Management Program. Furthermore, the WWMM allow the Master Plan to be updated quickly and easily as conditions change in the future.

The Waterways Management Model is a system of computer programs which analyzes watershed, channel and floodplain information. This system of programs performs the following analyses necessary for flood control planning and waterways management:

1. Computes damages, flood insurance costs, floodproofing costs and floodplain acquisition costs for the one percent event (1P01S1).

2. Computes erosion potential and estimates sediment; summarizes channel geometry (IP02S1).

3. Computes average annual damages (IP03S1).

4. Computes change in channel capacity with increase in roughness coefficient and sediment depth; estimates economic benefit of intensive maintenance (reduction in average annual damages when minimum roughness and sediment deposition are maintained) (IP04S1).

5. Does preliminary screening of flood damage reduction measures and funding programs applicable to each channel reach (IP05S1).

6. Does priority ranking of flood control project in each flood control zone according to advisory committee criteria (IP06S1).

7. Maintains a comprehensive data file of basic information on watershed, floodplain and channel characteristics (1P07S1).

8. Incorporates data developed from hydraulic analyses using HEC-II into the master data file for use by other WWMM programs (IP08S1).

9. Summarizes environmental quality characteristics for each reach of stream (IP09S1).

10. Incorporates the County's Assessors Master File into the data base for easy updating of property values in the floodplain (IP10S1).

CHAPTER 2
FLOODING & FLOOD DAMAGES

The purpose of this chapter is to document how flood damages are computed in the software program developed as part of the Waterways Planning Study. This chapter includes a section on methodology and a few examples of how the methodology is used. The Users Manual contains details of how to use the flood damage program, the input requirements and output available.

Methodology

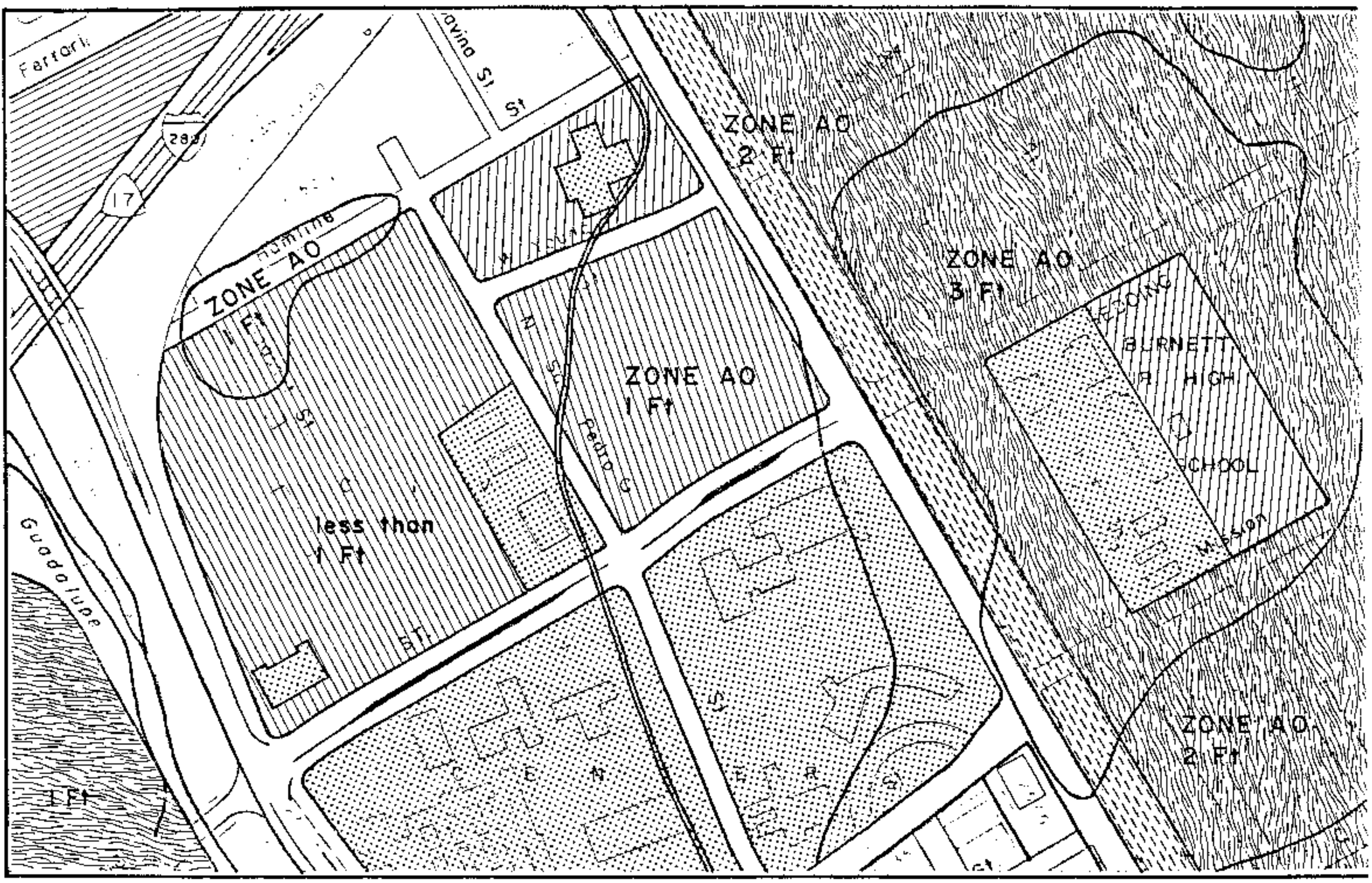
The information obtained to compute flood damages includes the area flooded, the land uses in the area flooded, the depth of flooding in the area flooded, the market value of properties in the area flooded and the relationship of depth of flooding to degree of damage. This section discusses how this information is obtained.

A. Area Flooded - Areas within the five flood control zones that would flood more than one foot deep during a one percent flood were identified in a study done in 1978 by George S. Nolte and Associates for the Federal Insurance Administration. One product of this study was a set of maps which showed the areas so flooded and water depths or water surface elevations. The base maps upon which the areas flooded are shown are the County of Santa Clara's 500-scale Cadastral maps dated January 1977. An example of a flood map is shown in Figure 4. Nolte also has provided the District with flood maps which show areas that flood to a depth less than one foot.

B. Depth of Flooding - Potential damages caused by floodwaters are estimated based on depth of flooding. Depth of flooding was determined from the Federal Insurance Studies. Where the water depth was specified by Nolte, the damages caused by flooding were determined using the specified water depth directly. Where the water surface elevation was specified by Nolte, depths were obtained by finding the elevation of the land and subtracting the land elevation from the water surface elevation. The

FIGURE 4

WATERWAYS PLANNING STUDY



SCALE : 1" = 500'

Land use designations from "Land Use Map of Santa Clara County, California" July, 1976, by CARTREMS lab, Department of Geography, San Jose State University.

▨ RD = DETACHED RESIDENTIAL
▨ LM = MIXED INDUSTRIAL / COMMERCIAL USE
▨ LS = PUBLIC SERVICE BUILDINGS
▨ OI = OPEN IMPROVED

"1 ft" = Depth of flooding during 100-year flow (from Nolte's work for the Federal Insurance Administration)

Base map = County of Santa Clara, 1 inch = 500 feet Cadastral maps dated January 1977.

land elevations were obtained from U. S. Geological Survey's 2,000-scale topographic maps.

The Federal Insurance Administration developed codes to specify land areas' relative flood hazards. The codes are based on depth of flooding, velocity of flow of floodwaters and frequency of flooding. The codes are called the "Special Flood Hazard Designation" system. A complete list of all the codes and how they are chosen is shown on the following page.

C. Land Use - The District defined the nine land use categories listed in Table 10 and divided each flooded area into subareas. Each subarea contained only one of the nine land uses. Land uses in each flooded area were determined using the "Land Use Map of Santa Clara Valley, California, July 1976" prepared by the CARTREMS Laboratory of the Department of Geography at San Jose State University.

D. Market Values of Structures and Their Contents - District real estate personnel estimated "Market Value" for land and structures in areas subject to flooding on each of the 500-scale base maps of the County. The estimates are based on list and actual sales prices of properties in or near floodplain areas, on average and median sales price information published by the San Jose Real Estate Board, and on other market value estimating techniques.

To determine the market value of structures in terms of dollars per acre, densities of structures per acre were estimated from aerial photos and from parcel delineations on the base maps. Estimating the market value of structures alone often involved separating out the cost of unimproved land in that land use category. A sample calculation to determine the per acre value of single family residences involves:

Estimated Market Value of Homes in Area x Avg. density of Homes per Acre = Estimated Market Value of Improved Residential Land per Acre

Explanation of Special Flood Hazard Areas Designated on Flood Insurance Rate Maps (FIRM)

Zone A:

Special Flood Hazard Areas inundated by the 100-year flood, determined by approximate methods, no base flood (1% flood) elevations or Flood Harzard Factors determined.

Zone A0:

Special Flood Hazard Areas inundated by types of shallow flooding where depths are between 1.0 and 3.0 feet and the product of the depths (in feet) and velocity (in feet per second) is less than 15. No base flood elevations shown or Flood Hazard Factors determined.

Zone AH:

Special Flood Hazard inundated by types of 100-year shallow flooding where depths are between 1.0 and 3.0 feet. The base flood elevations are shown, but no flood hazard factors are determined. This is a flood ponding area where flow velocities are minimal.

Zones A1-A30:

Special Flood Hazard Areas inundated by the 100-year flood, determined by detailed methods; base flood elevations shown, and zone designations assigned according to the Flood Hazard Factors. The Flood Hazard Factor (FHF) is the Federal Insurance Administration device used to correlate flood information with insurance rate tables. Correlations between property damage from floods and their FHF are used to set actuarial insurance premium rate tables based on FHFs from 005 to 200. The FHF for a reach is the difference between the 10- and 100-year flood water surface elevations expressed to the nearest one-half foot, and shown as a three digit code. For example, if the difference between water surface elevations of the 10- and 100-year floods is 0.7-foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 0.15; if the difference is 5.0 feet, the FHF is 050.

To convert Flood Hazard Factors (FHF) to FIA Zone designations:

FHF	ZONE	FHF	ZONE	FHF	ZONE
005	A1	055	A11	110	A21
010	A2	060	A12	120	A22
015	A3	065	A13	130	A23
020	A4	070	A14	140	A24
025	A5	075	A15	150	A25
030	A6	080	A16	160	A26
035	A7	085	A17	170	A27
040	A8	090	A18	180	A28
045	A9	095	A19	190	A29
050	A10	100	A20	200	A30

Zone B:

Areas between the Special Flood Hazard Area and the limits of the 500-year flood, including areas of the 500-year floodplain that are protected from the 100-year flood by dike, levee, or other water control structure; and areas subject to certain types of 100-year shallow flooding where depths are less than 1.0-foot. Area subject to shallow flooding during the 100-year flood due to inadequate local drainage. In general, the FIRM maps designate all the area within a city as Zone B. The limited capacity of the storm drainage system will subject almost all of the city to shallow sheetflow during the 100-year flood as floodwaters in excess of the storm drain capacity flow down the streets.

Zone C:

Areas not subject to flooding by the 500-year flood, including areas that are protected from 500-year floods by dike, levee, or other water control structure.

Zone V1-V30:

Special Flood Hazard Areas along coasts inundated by the 100-year flood, as determined by detailed methods, and that have additional hazards due to velocity (wave action).

Explanation of Special Flood Hazard Areas Designated on Flood Insurance Rate Maps (FIRM)

Zone A:

Special Flood Hazard Areas inundated by the 100-year flood, determined by approximate methods, no base flood (1% flood) elevations or Flood Harzard Factors determined.

Zone A0:

Special Flood Hazard Areas inundated by types of shallow flooding where depths are between 1.0 and 3.0 feet and the product of the depths (in feet) and velocity (in feet per second) is less than 15. No base flood elevations shown or Flood Hazard Factors determined.

Zone AH:

Special Flood Hazard inundated by types of 100-year shallow flooding where depths are between 1.0 and 3.0 feet. The base flood elevations are shown, but no flood hazard factors are determined. This is a flood ponding area where flow velocities are minimal.

Zones A1-A30:

Special Flood Hazard Areas inundated by the 100-year flood, determined by detailed methods; base flood elevations shown, and zone designations assigned according to the Flood Hazard Factors. The Flood Hazard Factor (FHF) is the Federal Insurance Administration device used to correlate flood information with insurance rate tables. Correlations between property damage from floods and their FHF are used to set actuarial insurance premium rate tables based on FHFs from 005 to 200. The FHF for a reach is the difference between the 10- and 100-year flood water surface elevations expressed to the nearest one-half foot, and shown as a three digit code. For example, if the difference between water surface elevations of the 10- and 100-year floods is 0.7-foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 0.15; if the difference is 5.0 feet, the FHF is 050.

To convert Flood Hazard Factors (FHF) to FIA Zone designations:

FHF	ZONE	FHF	ZONE	FHF	ZONE
005	A1	055	A11	110	A21
010	A2	060	A12	120	A22
015	A3	065	A13	130	A23
020	A4	070	A14	140	A24
025	A5	075	A15	150	A25
030	A6	080	A16	160	A26
035	A7	085	A17	170	A27
040	A8	090	A18	180	A28
045	A9	095	A19	190	A29
050	A10	100	A20	200	A30

Zone B:

Areas between the Special Flood Hazard Area and the limits of the 500-year flood, including areas of the 500-year floodplain that are protected from the 100-year flood by dike, levee, or other water control structure; and areas subject to certain types of 100-year shallow flooding where depths are less than 1.0-foot. Area subject to shallow flooding during the 100-year flood due to inadequate local drainage. In general, the FIRM maps designate all the area within a city as Zone B. The limited capacity of the storm drainage system will subject almost all of the city to shallow sheetflow during the 100-year flood as floodwaters in excess of the storm drain capacity flow down the streets.

Zone C:

Areas not subject to flooding by the 500-year flood, including areas that are protected from 500-year floods by dike, levee, or other water control structure.

Zone V1-V30:

Special Flood Hazard Areas along coasts inundated by the 100-year flood, as determined by detailed methods, and that have additional hazards due to velocity (wave action).

TABLE 10

DATA USED TO COMPUTE FLOOD DAMAGES

Land Use Type	Market Value of Structure (Percentage of the Market Value of the Whole Property)	Non-Structural Damages	Value of Contents (Percentage of Market Value of the Structure)	Indirect Damage (Percentage of Direct Damages)	Figure Containing Appropriate Depth/Damage Curve
Residential					
Single Family Detached	73		30	15	6A
High Density	73		30	15	6B
Mobile Home	73		30	15	6C
Commercial	68		200	35	6D
Industrial	69		250	45	6E
Public Bldgs.	$3.14 M[1/]		200	34	6F
Open					
Improved		$200/acre		10	No Curve
Agriculture					
Perennial Crops		$36/acre			
Annual Crops		$65/acre		0	No Curve
Vacant		0		0	No Curve

[1/] Estimated average replacement cost in October 1981.

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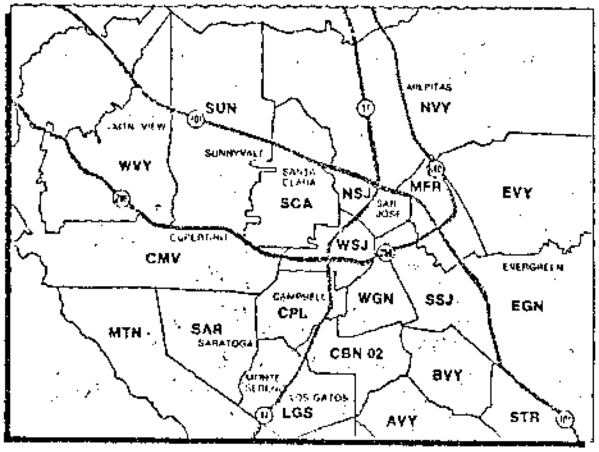
The objective is to determine an average per acre value of structures and land in each land use category which is consistent with the information on hand. At times, it is better to separate out single large structures when their market value is known or can be estimated. For example, the market value of a hospital can be estimated using a "dollars per bed" formula and this property is treated separately from other property in the same general land use category of "Livelihood-Services". Similarly, schools in the services land use category are estimated to have an average value of $3.14 million, their replacement cost in October, 1980. All market values are updated using a property value index, which is the median sales price of homes in San Jose as published by the San Jose Real Estate Board (Figure 5). For example the median sales price of homes in San Jose in October 1980 as listed by the San Jose Real Estate Board was $117,600. To find the current flood damages based on current market values, all market values are multiplied by the current median sales price of homes in San Jose divided by $117,600.

To include damages to the contents of structures in flood damage estimates, the value of the contents of a structure was estimated by assuming the percentages shown in Table 10 for each land use.

E. Damages - Damages were classified as direct and indirect, based upon whether a specific item in the flooded area is damaged.

1. Direct Damages - Direct damages can be broken down into two subcategories (1) damages to properties upon which structures are located and (2) damages to open land. Several agencies (U. S. Corps of Engineers, U. S. Soil Conservation Service, SRI, etc.) have done studies of the amount of direct damage to structures and their contents that is caused by various depths of floodwater. The results of these studies are "depth-damage curves", graphs which relate floodwater depth to a direct damage where the damage is expressed as a percentage of the market value of the structure and its contents. Figures 6A through 6F show, for

FIGURE 5



Map shows how the real estate boards divide the valley into neighborhood regions.

Previous 90 days.

Residential Sales

Area	Number Of Sales	Sales Total	*Median Price	Average Price	Ave. Days To Sale
Almaden Valley	162	$27,823,300	$159,900	$171,749	43
Blossom Valley	419	$46,103,490	$105,000	$110,032	33
Cambrian Park	282	$30,621,000	$105,000	$108,585	33
Campbell	144	$17,031,530	$112,000	$118,275	33
Cupertino-Monta Vista	211	$30,496,740	$131,500	$144,534	36
East Valley	158	$15,680,670	$84,000	$99,245	41
Evergreen	177	$18,537,000	$96,950	$104,729	37
Los Gatos	84	$19,570,720	$152,000	$232,985	54
Mayfair	159	$12,508,830	$75,900	$78,672	37
Morgan Hill-Gilroy	177	$26,257,780	$105,500	$148,349	48
Mountain property	21	$4,341,520	$170,000	$206,739	82
North San Jose	35	$2,807,490	$79,950	$80,214	39
North Valley	390	$42,947,710	$101,000	$110,122	38
Santa Clara	152	$17,340,050	$110,000	$114,079	36
Santa Teresa	139	$14,840,750	$97,400	$106,768	30
Saratoga	55	$14,358,670	$239,000	$261,067	49
South San Jose	228	$21,204,600	$83,500	$93,003	41
Sunnyvale	91	$12,151,220	$92,000	$133,530	42
West San Jose	94	$10,335,390	$99,000	$109,951	36
West Valley	20	$3,116,570	$120,000	$155,829	43
Willow Glen	158	$20,460,100	$113,000	$129,494	41
San Jose Real Estate Board		**Oct. 1980**	**$117,584**	**$103,000**	
		Oct. 1979	**$96,603**	**$85,500**	

Condominiums, Townhouses

Area	Number Of Sales	Sales Total	*Median Price	Average Price	Ave. Days To Sale
Almaden Valley	12	$1,429,400	$132,500	$119,117	30
Blossom Valley	105	$8,186,840	$73,950	$77,970	37
Cambrian Park	36	$3,170,200	$79,000	$88,061	37
Campbell	42	$4,768,620	$106,950	$113,539	28
Cupertino-Monta Vista	47	$5,805,890	$124,000	$123,530	29
East Valley	11	$1,046,000	$96,500	$95,091	43
Evergreen	25	$1,790,350	$70,000	$71,614	38
Los Gatos	22	$3,085,200	$135,000	$140,236	30
Mayfair	26	$1,854,170	$70,950	$71,314	47
Morgan Hill-Gilroy	14	$1,133,900	$71,000	$80,993	37
North Valley	111	$8,894,600	$80,000	$80,132	39
Santa Clara	42	$4,629,510	$105,000	$110,226	37
Santa Teresa	6	$576,500	$95,000	$96,083	55
South San Jose	21	$1,440,330	$68,100	$68,587	54
Sunnyvale	22	$2,416,700	$111,000	$109,850	45
West San Jose	12	$1,316,350	$104,600	$109,696	30
West Valley	19	$2,232,900	$105,000	$117,521	52
Willow Glen	21	$2,626,590	$113,000	$125,076	54
San Jose Real Estate Board		**Oct. 1980**		**$96,093**	
		Oct. 1979		**$79,718**	

*—Median sales price is the mid-point above half the sales and below the other half.

(Above sales statistics compiled by San Jose Real Estate Board)

Average Home Prices
by
San Jose Real Estate Board

FIGURE 6A

SINGLE FAMILY RESIDENTIAL

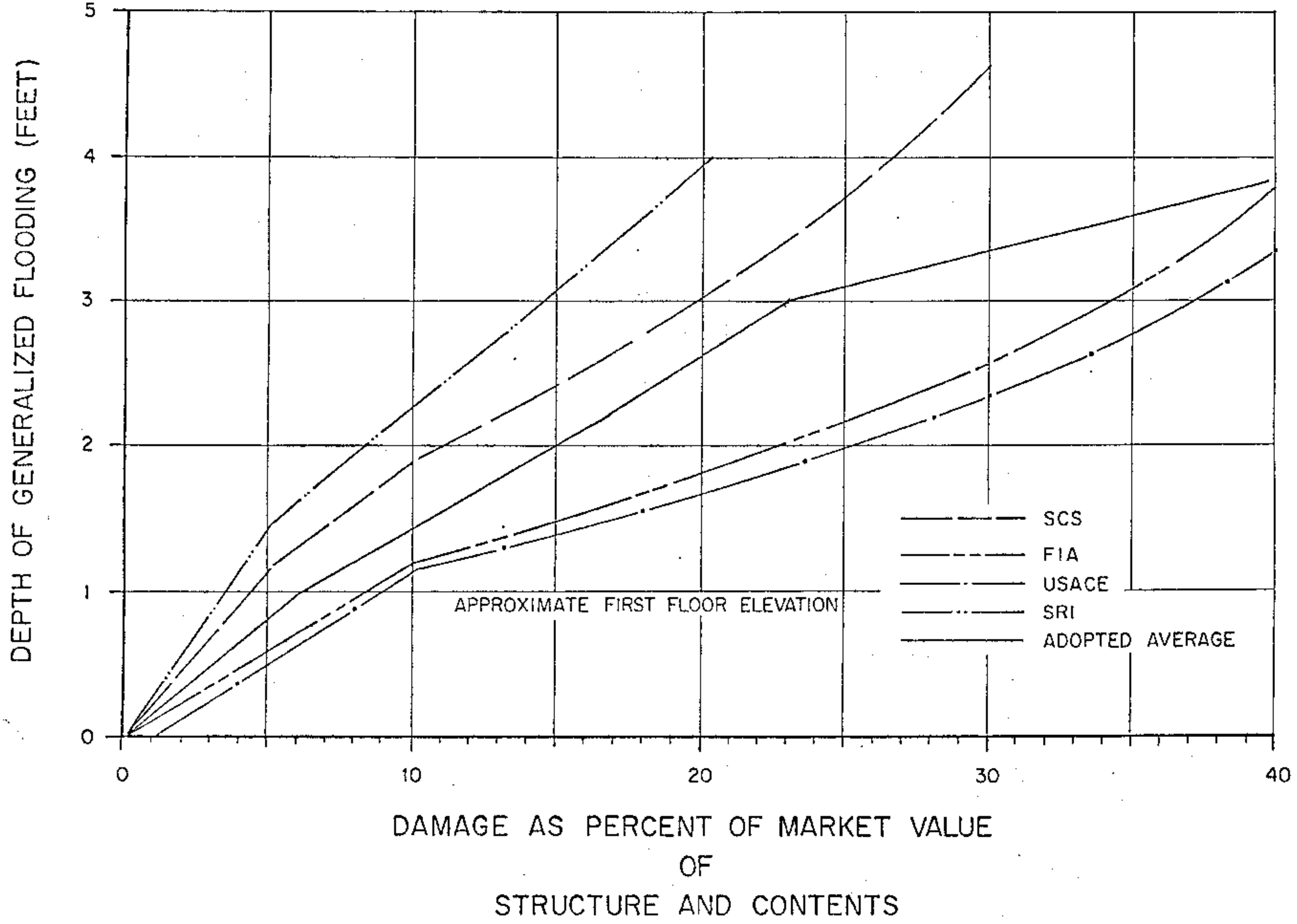
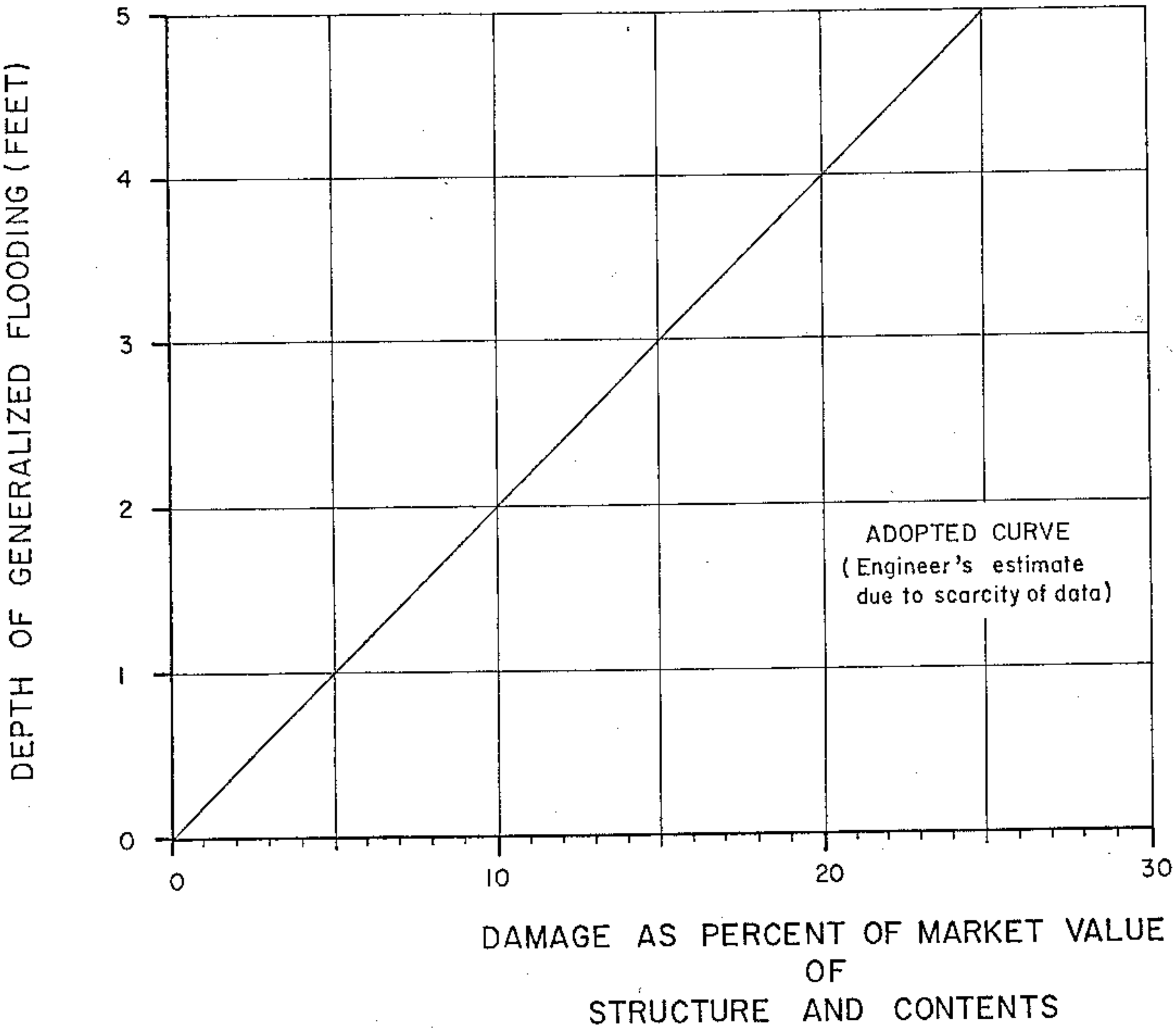


FIGURE 6B

HIGH DENSITY RESIDENTIAL



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MOBILE HOMES

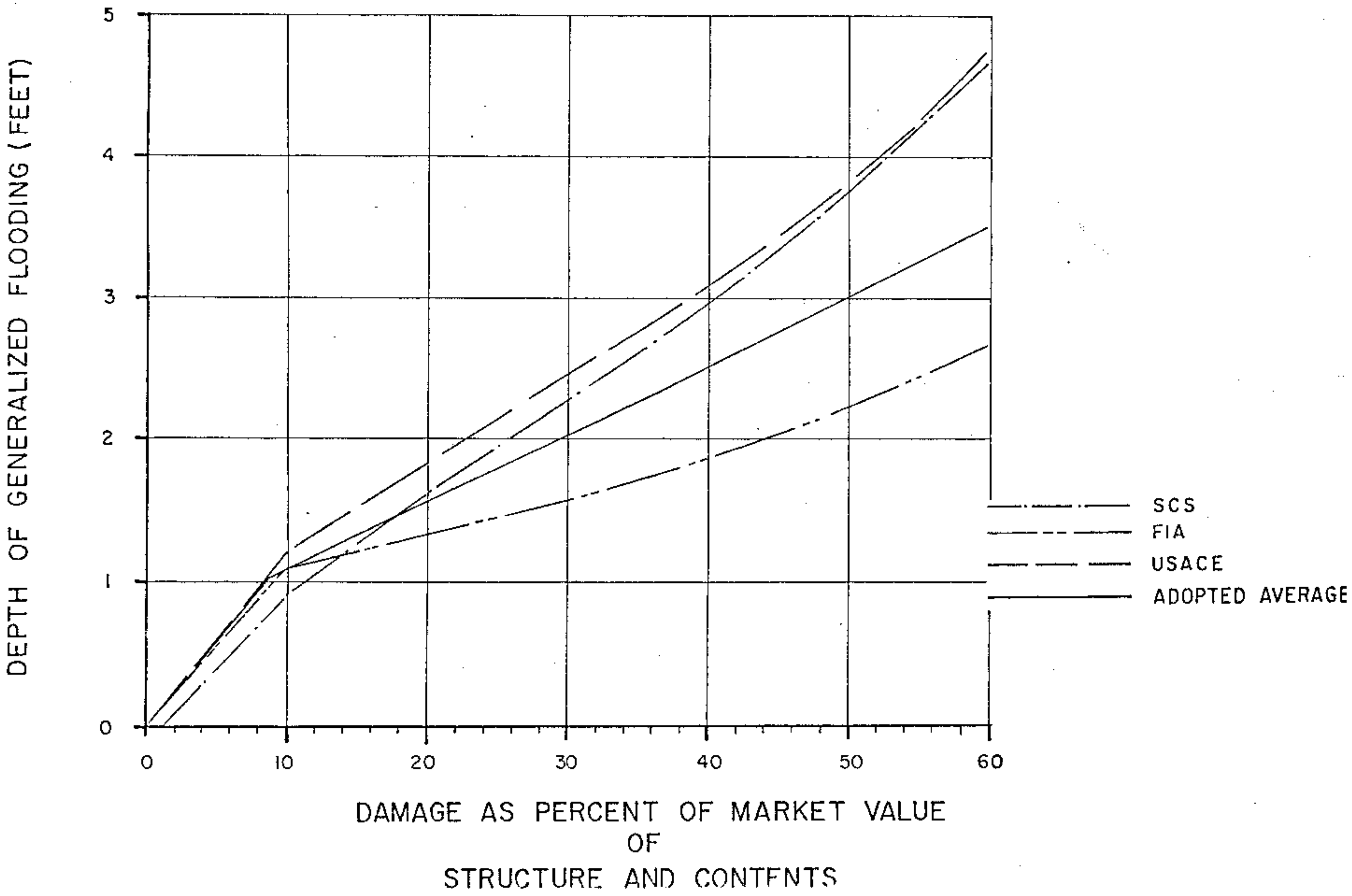


FIGURE 6B

COMMERCIAL

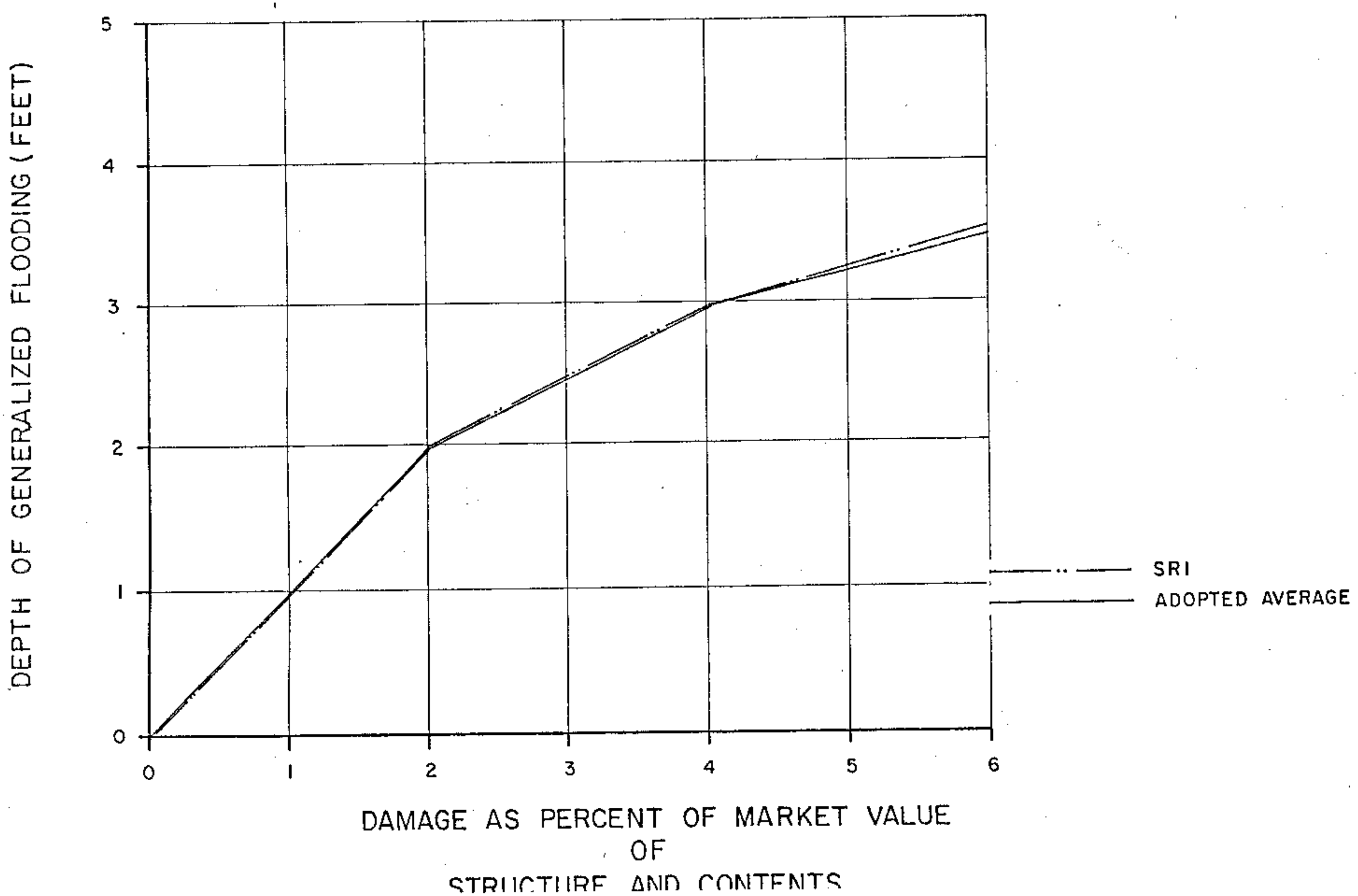


FIGURE 6E

INDUSTRIAL

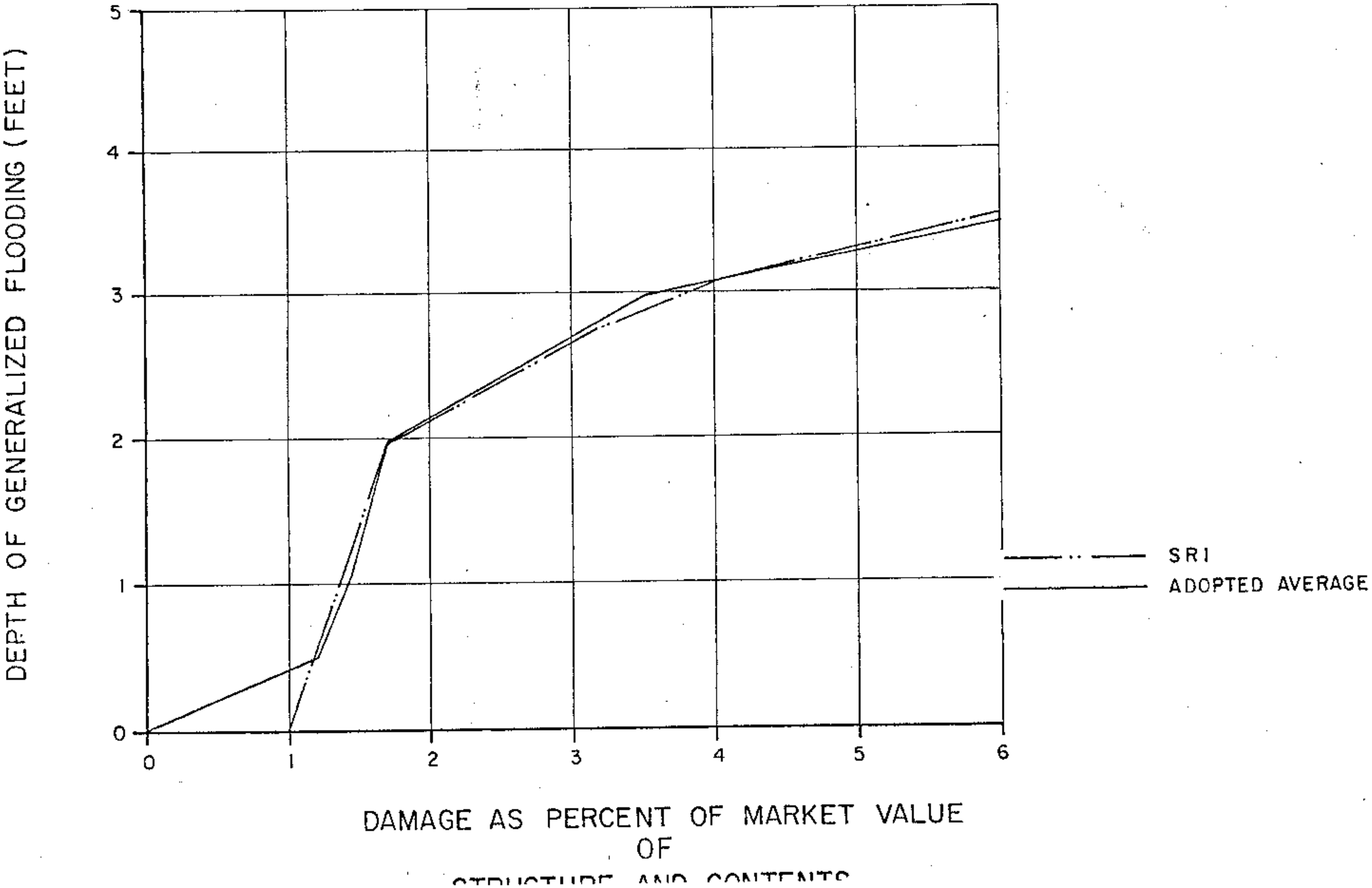
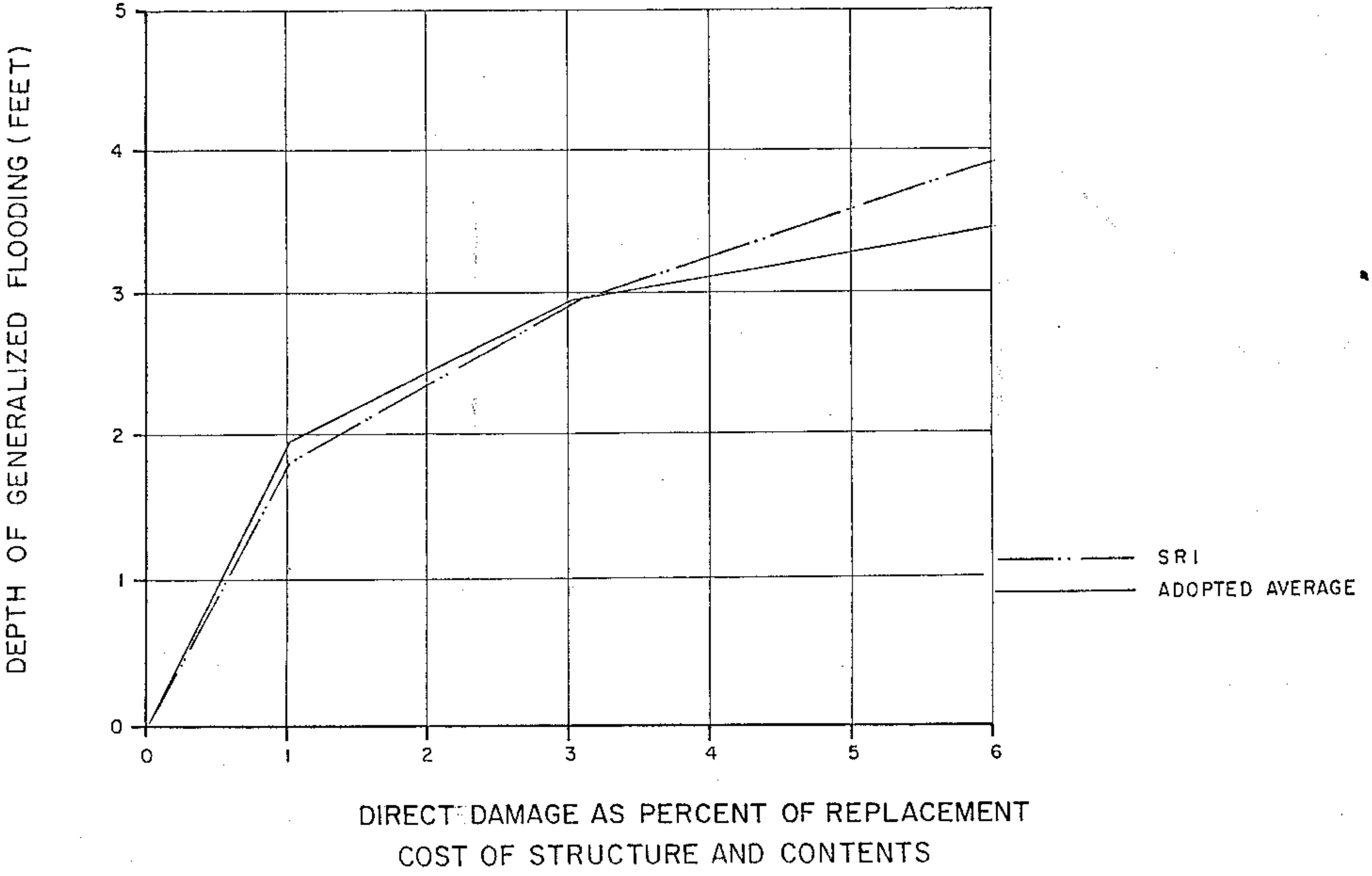


FIGURE 6F

PUBLIC BUILDINGS



each land use, the curves generated by previous studies and the curve that the District has selected for use.

Properties that have no structures suffer approximately the same level of damage for all depths of flooding. The damage is either the cleanup cost for open improved land, which can be assumed to be $200/acre, or the value of lost crops for agricultural land, $35 and $65/acre for perennial and annual crops, respectively. Vacant land is assumed to suffer no damage.

2. Indirect Damages - Indirect damages include the value of lost business, costs of cleanup, safeguarding health, rerouting traffic and so on. It is difficult to assess the value of indirect damages accurately. The current "state of the art" is to assume indirect damages are a percentage of the direct damage; that percentage is assumed to be different for different land uses. The District has chosen to use estimates of these percentages developed by the U. S. Corps of Engineers. The Corps estimates are in Table 10.

3. Average Annual Damages - The curve in Figure 7A illustrates the relationship between flood damage and probability of exceedance. The area under the curve is the average annual flood damage in dollars per year.

When evaluating the effectiveness of various flood protection plans there wll generally be residual flood damages for each alternative, due to flood events larger than the design event. The residual damage is the area under the damage-frequency curve after the selected alternative is implemented. The reduction in the annual flood damage potential is the principal benefit realized if the flood control measure is constructed. The average annual benefit is illustrated in Figure 7B as the areas between the pre-project damage frequency curve and the post-project frequency curve.

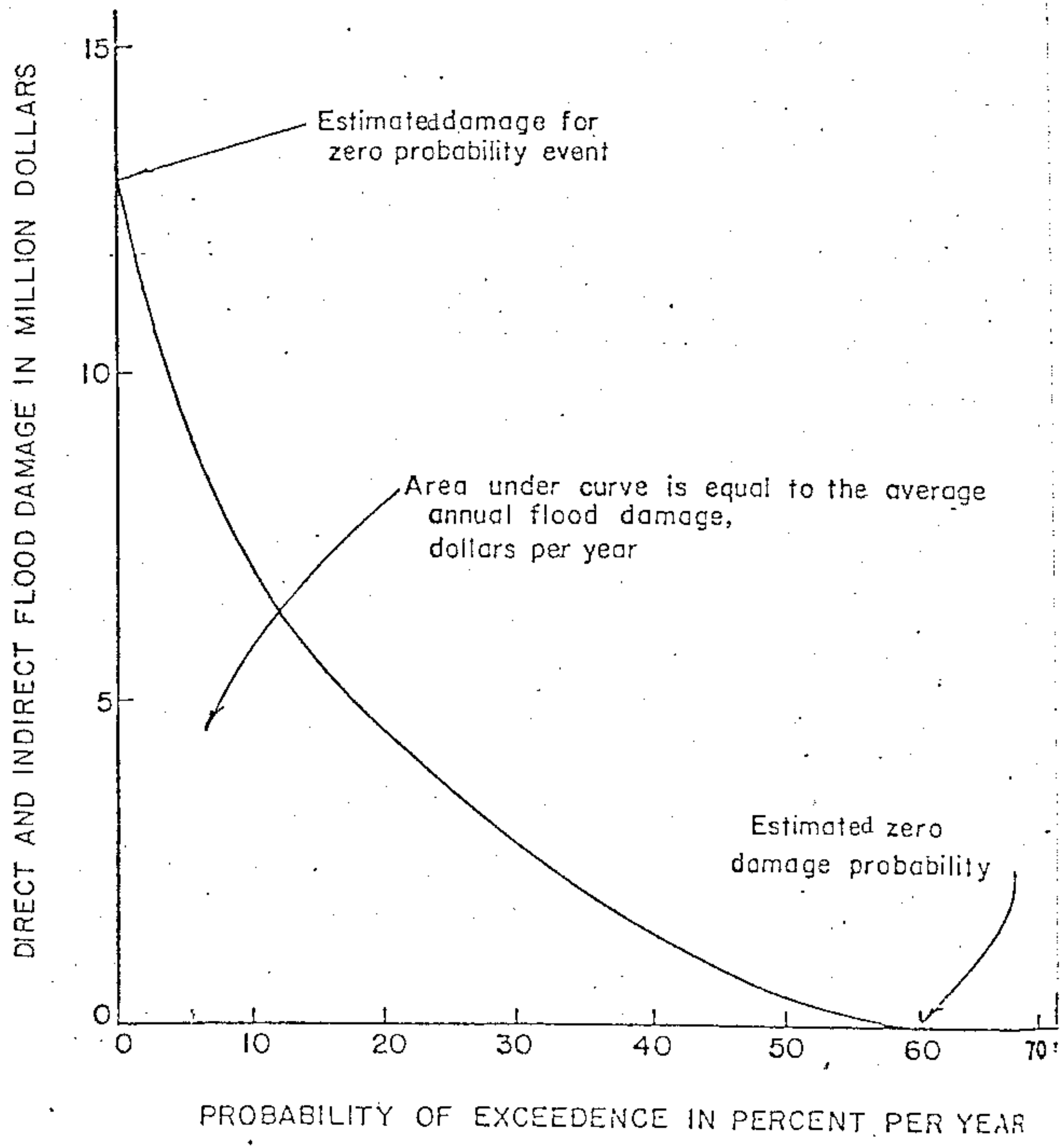
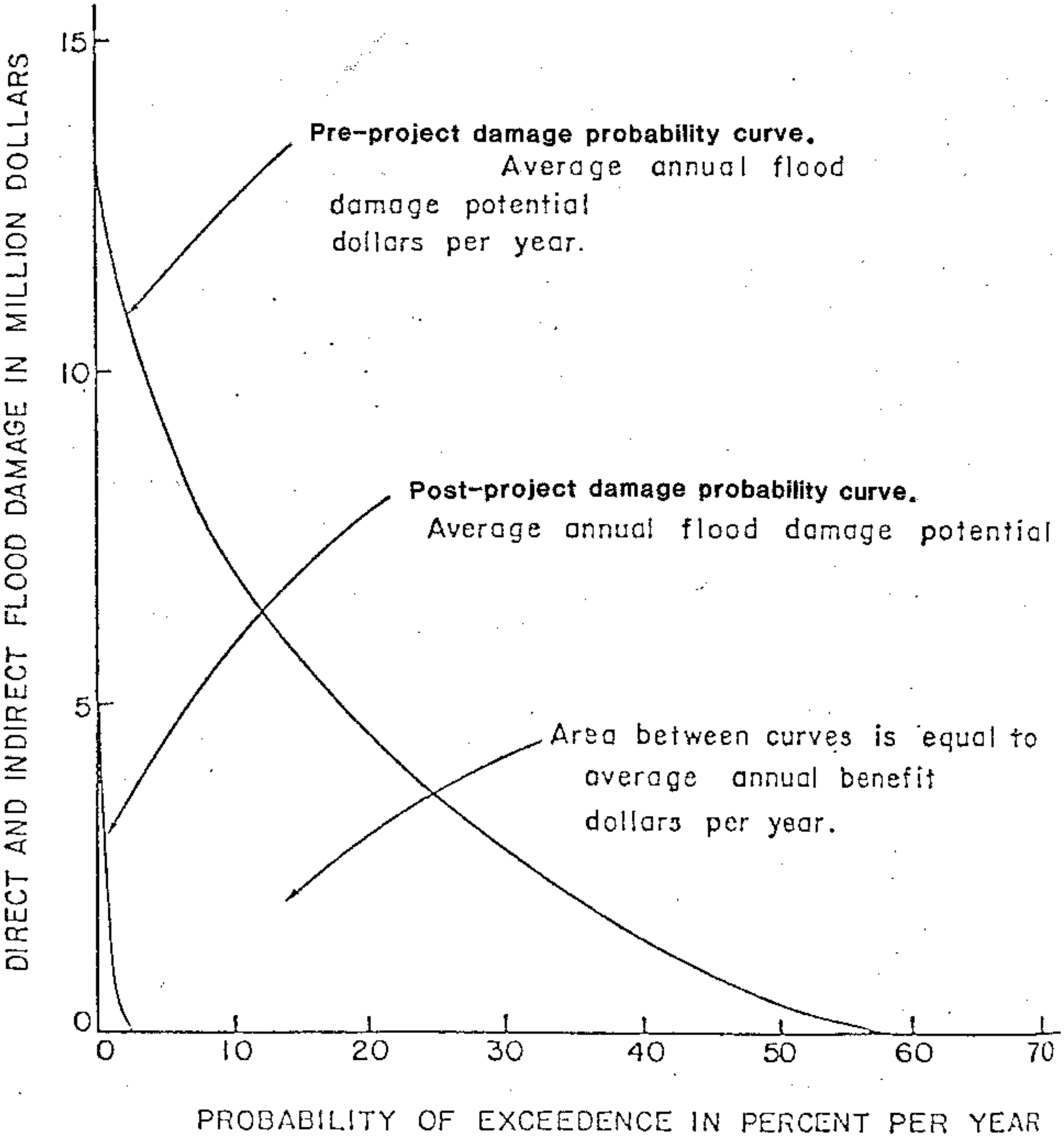

15
10
5
0
0
10
20
30
40
50
60
70
DIRECT AND INDIRECT FLOOD DAMAGE IN MILLION DOLLARS
PROBABILITY OF EXCEEDENCE IN PERCENT PER YEAR
Estimateddamage for zero probability event
Area under curve is equal to the average annual flood damage, dollars per year
Estimated zero damage probability

FIGURE 7A

FIGURE 7B


Pre-project damage probability curve. Average annual flood damage potential dollars per year.
Post-project damage probability curve. Average annual flood damage potential
Area between curves is equal to average annual benefit dollars per year.
DIRECT AND INDIRECT FLOOD DAMAGE IN MILLION DOLLARS
0
5
10
15
0
10
20
30
40
50
60
70
PROBABILITY OF EXCEEDENCE IN PERCENT PER YEAR

The damage-frequency curve is usually prepared by estimating damages for three, four or more events. Because of the preliminary nature of the present study there is only one point (1% damages and frequency of flooding) which can be used.

When the District constructs a flood control project the principal benefit is a reduction in the annual flood damage potential. The average annual benefit from construction of a 1% capacity project will be the area shown in Figure 7C. This average annual benefit is estimated as the area under the triangular section multiplied by a correction factor, CF:

Average Annual Benefit =

$$\frac{\text{(Frequency of flooding + .01)}}{2} \text{ X (1\% Damages) X C + (1\% Damages X .01)}$$

The correction factor, CF, has been developed to adjust the triangular area such that approximates move closely the area under a typical damage curve. For a channel which floods infrequently the triangular area calculation is a fair approximation of the actual damage curve so the CF is very nearly 1.0. The variation of the CF with the frequency of flooding is plotted in Figure 7D.

In designing flood control channels it is important to differentiate between a robust solution to a flooding problem and a brittle one. The difference lies in the damages which are expected in the event a flood greater than the 100-year flood occurs. For example, a channel which is mainly concrete is not expected to fail in the event its design flow is exceeded and residual damages are limited to those shown in Figure 7C. This is called a "robust" flood damage reduction solution. However, if levees are part of the flood control measure, the project may fail in the event the design flow is exceeded. Damages would then be the residual damages, as well as some or all of the damages meant to be prevented by the project for the design flow and smaller flows.

FIGURE 7C

TYPICAL FLOOD DAMAGE CURVE

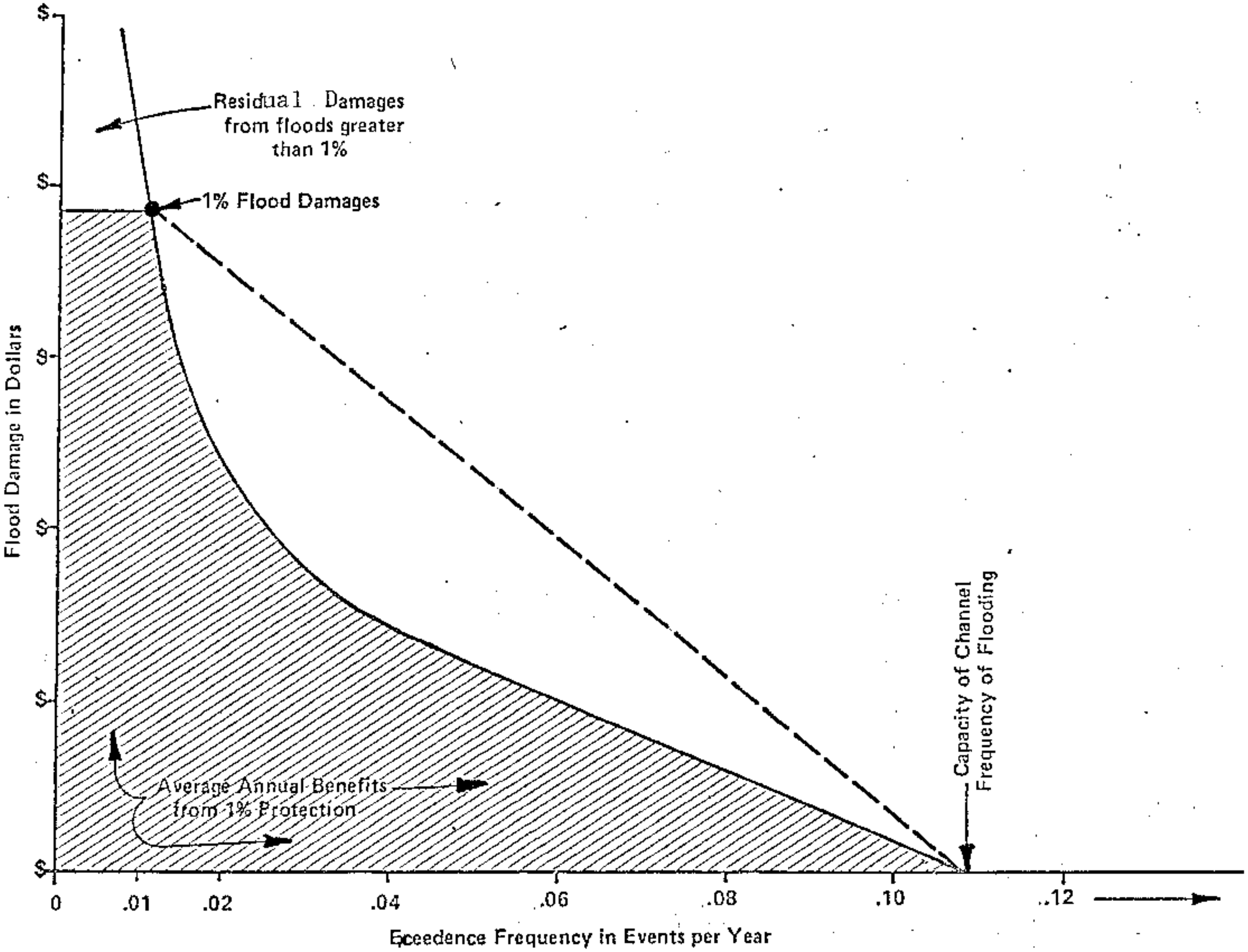
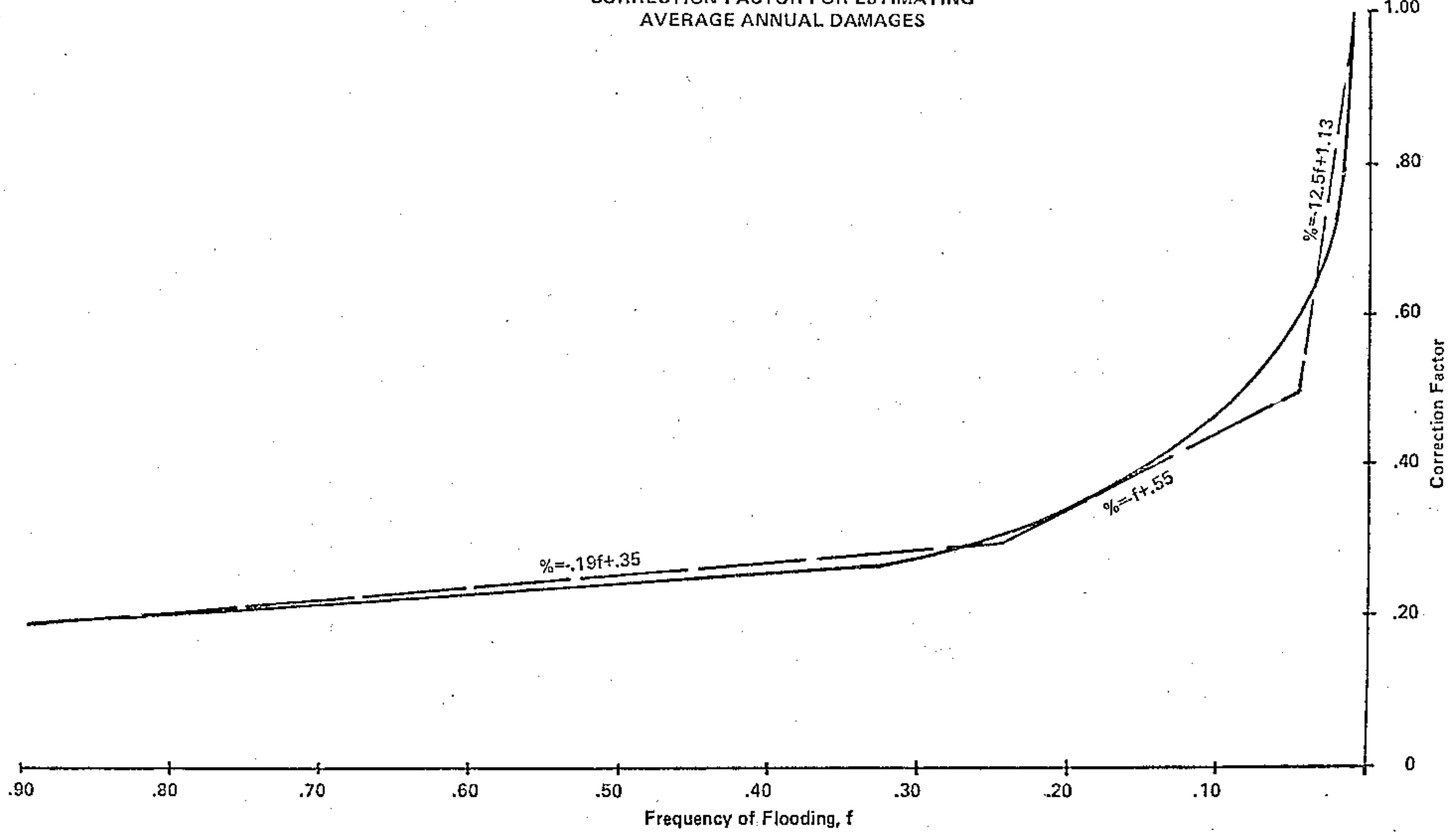


FIGURE 7D

CORRECTION FACTOR FOR ESTIMATING
AVERAGE ANNUAL DAMAGES



This kind of flood reduction solution is called "brittle". For a brittle solution, if the design flow is exceeded the damages could be greater than if the flood control measure had not been constructed.

Examples

This section presents example calculations of direct damages for four different land uses: residential, public service facilities, open improved and agricultural.

Example 1

Example Flood Damage Calculations

Land Use Type: Single Family Detached

Given:

Area: 100 acres subject to less than one foot flooding
200 acres subject to two feet of flooding

Density: 5 dwelling units/acre

Market value of structure: $80,200/dwelling unit

Calculations: Determine value of contents of structure from data in Table 10.

Contents value = 30% structure value = .3 x $80,200/DU
= $24,060/DU

Total value structure + contents = 80,200 + 24,060 = $104,260/DU

Value per acre = (cost per unit) x (units per acre)
= ($104,260/DU) x (5DU/acre)
= $521,300/acre

Determine percent damage for each water depth from Figure 6A.

Water Depth (ft)	% Damage
1	3
2	15

Determine damages:

Damages = (Area flooded) x (value/acre) x (percent damage)

Damage from Less Than 1 Foot Flooding

= 100 acres x $.521M/acre x .03 = $1.56 M.

Damage from 2 Foot Flooding

= 200 acres x $.521M/acres x 0.15 = 15.6M

Total Damages = $1.56M + $15.6M = **$17.2M**

Example 2

Land Use Type: Public Services Buildings (school)

Given: Area: 3 acres subject to 2-foot flooding
2 acres subject to 3-foot flooding

Density: 1 school/5 acres = 0.2 units/acre

Market Value of Structure: Replacement value $3.15M

Calculations: Determine value of contents from data in Table 10.

Contents Value = 200% of structural value = 2 x $3.15M $6.30M

Total Value = $6.30M + $3.15M = $9.45M

Value Acre $= \frac{\text{Total Value}}{\text{Units}} \times \frac{\text{Units}}{\text{Acre}}$

$= \$9.45\text{M/Unit} \times \frac{2 \text{ Unit}}{\text{Acre}} = \$1.89\text{M/Acre}$

Determine percent damage for each depth from Figure 6D

Water Depth (ft)	Percent Damage
2	1%
3	3%

Determine Damages:

Damages = acres flooded x value/acre x percent damage

Damages for 2-foot depth

$= 2 \text{ acres} \times \frac{\$1.89\text{M}}{\text{acre}} \times 0.01 = \$.0567\text{M}$

Damages for 3-foot depth

$= 2 \text{ acres} \times \frac{\$1.89}{\text{acre}} \times 0.03 = \$.1134\text{M}$

Total Damages = $.1134 + .0567 = $0.17M

Example 3

Land Use Type: Open Improved Land

Given: Area: 10 acres flooded 1 foot deep
5 acres flooded 2 feet deep

Market Value of Structure = $0M

Calculations: Determine damages for each depth (from Table 10)

Water Depth (Ft)	Damages
2	$200/acre cleanup
3	$200/acre cleanup

Determine Damages:

Damages = area flooded x the cleanup cost

Damages for 1 foot flood
= 10 acres x $200/acre = $2,000

Damages for 2-foot flood
= 5 acres x $200/acre = $1,000

Total Damages = $3,000

Example 4

Land Use Type: Agricultural Land

Given: Area: 80 acres of orchard subject to 1 foot of flooding
40 acres of row crops subject to 2 feet of flooding

Market Value = $OM

Calculation: Determine Unit Damages

Orchards - $36/acre*
Row crops - $65/acre*

*irrespective of depth

Determine Total Damages

Total Damages

= (80 acres of orchard x $36/acre)
+ 40 acres of row crop x $65/acre

= $45,480

CHAPTER 3
EROSION

Erosion problem areas within and along waterways have been identified using two analytical methods and by field inspection. This chapter describes the analytical methods and gives examples of their use. The methods are applied using a computer program developed as part of the Waterways Planning Study. The input requirements and output available are described in detail in the Users Manual.

The severity of existing erosion problems were evaluated in terms of the definitions in Table 11. These definitions were adopted to standardize the evaluation of erosion problem areas and simplify assigning priorities to them. These definitions also were used to evaluate the possibility of erosion occurring during more extreme events using the analytical methods described below.

Analytical Methods

The analytical methods used were the "Allowable Velocity Method" and the "Tractive Force Method". Both are presented in "Planning and Design of Open Channels" 1/ by the U.S. Soil Conservation Service.

Allowable Velocity Method

The Allowable Velocity Method determines the maximum flow velocity in a channel that will not cause erosion. If the actual flow velocity exceeds the maximum allowable velocity, then erosion results. SCS developed the method from data presented by Fortier and Scoby2/, by Lane3/ and by investigators in the USSR4/. The results of this work are presented in Figure 8 which presents maximum allowable velocities for the following conditions:

- Straight earth-lined channels
- No vegetative or structural protection
- Water depth equal to one meter
- Flood flowrates with a 10% probability of occurrence
- Very flat banks

TABLE 11

DEFINITIONS FOR CLASSIFYING EROSION PROBLEMS

1.0	STABLE	There is no physical evidence of erosion problems and tractive force analysis indicates permissible velocities are greater than actual velocities
2.0	POTENTIAL	Bank appears stable but tractive force analysis indicates potentially erosive velocities
3.1	ACTIVE (NEGLIGIBLE)	Less than 3 inches of soil has eroded from bank channel practically in as-built condition
3.2	ACTIVE (SLIGHT)	Between 3 and 12 inches of soil has eroded from bank
3.3	ACTIVE (MODERATE)	Between 1 and 3 feet of soil has eroded from bank
3.4	ACTIVE (SEVERE)	More than 3 feet of soil has eroded from bank
4.0	URGENT	Bank is actively eroding away and poses an immediate threat to structure; or threatens consequences such as total levee failure or drop structure failure; or threatens the disruption of public roadway or operations of public utilities

FIGURE 8

MAXIMUM ALLOWABLE VELOCITIES

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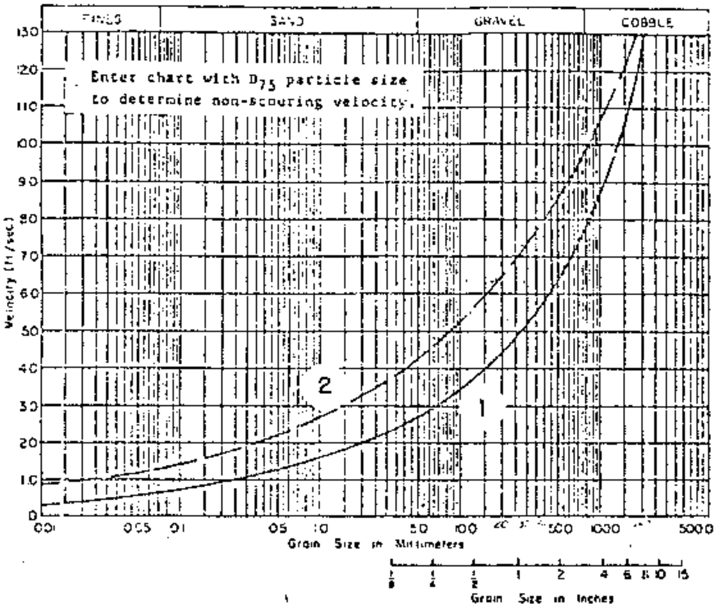
NON-SCOURING VELOCITIES FOR VARIOUS EARTH MATERIALS

SOIL DESCRIPTIONS	SOIL CLASSI-FICATION		VELOCITY (FT./SEC.)		
	GROUP	PI	CLEAR WATER	SUSPENDED LOAD	BEDLOAD
Stiff clay, high cohesion	CH	Above 20	4.5	6.0	3.5
Lean to moderately cohesive clays; silty or sandy clays.	CL	7-10	Curve 1	Curve 2	*
	CL	10-20	2.5	4.0	2.5
	CL	Above 20	4.0	5.5	3.5
Colloidal alluvial silts; micaceous or diatomaceous silts; organic silts and clays with high LL.	MH, OH	Below 10	Curve 1	Curve 2	*
	MH, OH	10-20	2.5	4.0	2.5
	MH, OH	Above 20	3.5	5.0	3.0
Non-colloidal alluvial silts sandy or clayey silts; organic silts with low LL.	ML, OL	Below 10	Curve 1	Curve 2	*
	ML, OL	10-20	2.5	4.0	2.5
Silty sands or gravelly silty sands containing more than 5% fines.	SM	Below 10	Curve 1	Curve 2	*
	SM	10-20	2.5	4.0	2.5
Clayey sand or gravelly clayey sands containing more than 5% fines.	SC	7-10	Curve 1	Curve 2	*
	SC	10-20	2.5	4.0	2.5
	SC	Above 20	4.0	6.0	3.5
Clayey gravels or clayey sandy gravels containing more than 5% fines.	GC	7-10	Curve 1	Curve 2	*
	GC	10-20	Curve 1 or 4.0	Curve 2 or 5.5	* or 5.0
	GC	Above 20	Curve 1 or 5.0	Curve 2 or 6.5	* or 6.0
Silty gravels or silty sandy gravels containing more than 5% fines.	GM	Below 10	Curve 1	Curve 2	*
	GM	10-20	Curve 1 or 4.0	Curve 2 or 5.5	* or 5.5
Clean sands and gravels or sand-gravel mixtures containing less than 5% fines.	GW	-	Curve 1	Curve 2	*
	GP	-	Curve 1	Curve 2	
	SW	-	Curve 1	Curve 2	
	SP	-	Curve 1	Curve 2	



Enter chart with D_{75} particle size to determine non-scouring velocity.

*Use curve number 1 if the bed load concentration is less than the capacity of the stream or if the size of the bed load material is larger than the D_{75} size of the channel materials. Use curve number 2 if the bed load concentration is equal to the capacity of the stream or if the size of the bed load material is smaller than the D_{75} size of the channel materials.

Note:
In no case should the allowable velocity be exceeded by the 10% chance discharge regardless of the frequency of occurrence of the design flow.

In this analysis values for "suspended load" were used. Since conditions in most cases will be different from those upon which Figure 8 is based, SCS also developed a method for adjusting the "initial" allowable velocity obtained from Figure 8. The method involves multiplying the initial allowable veloctiy found in Figure 8 by one or more constants depending on existing conditions. The correction factors are found using the graphs in Figure 9. The type of soil, whether it is cohesive or not, effects how the adjustment procedure is applied, as follows:

1. Coarse Grained and Fine Grained Non-Cohesive Soils

The initial allowable velocity in channels in non-cohesive soils is found using Curve #2 in the graph in Figure 8. This determines allowable velocity based on soil D75 grain size. Adjustments to the initial allowable velocity are made if the existing water depth or channel side slopes are different than those assumed in Figure 8. The adjusted allowable velocity is found as follows:

(1) $V_a = V_i \times D \times B$

Where:

V_a = adjusted maximum allowable velocity

V_i = initial maximum allowable velocity (from Figure 8)

D = adjustment factor for depth (from Figure 9a, "Depth of Design Flow" graph)

B = adjustment factor for bank slope (from Figure 9b, "Bank Slope" graph)

2. Fine Grained Cohesive Soils

The initial allowable velocity in channels in cohesive soils is found from the table in Figure 8 without reference to the graph. Adjustments to the initial allowable velocity are made for variations of existing water depth and flood frequency from that assumed for Figure 8. The adjustment is:

(2) $V_a = V_i \times D \times F$

Where:

V_a = adjusted maximum allowable velocity

V_i = initial maximum allowable velocity (from Figure 8)

D = adjustment factor for depth (from Figure 9a, "Depth of Design Flow" graph

B = adjustment factor for bank slope (from Figure 9b, "Bank Slope" graph

F = adjustment factor for differences in flood frequency (from Figure 9c, "Frequency of Design Flow" graph)

FIGURE 9

CORRECTION FACTORS FOR MAXIMUM ALLOWABLE VELOCITY

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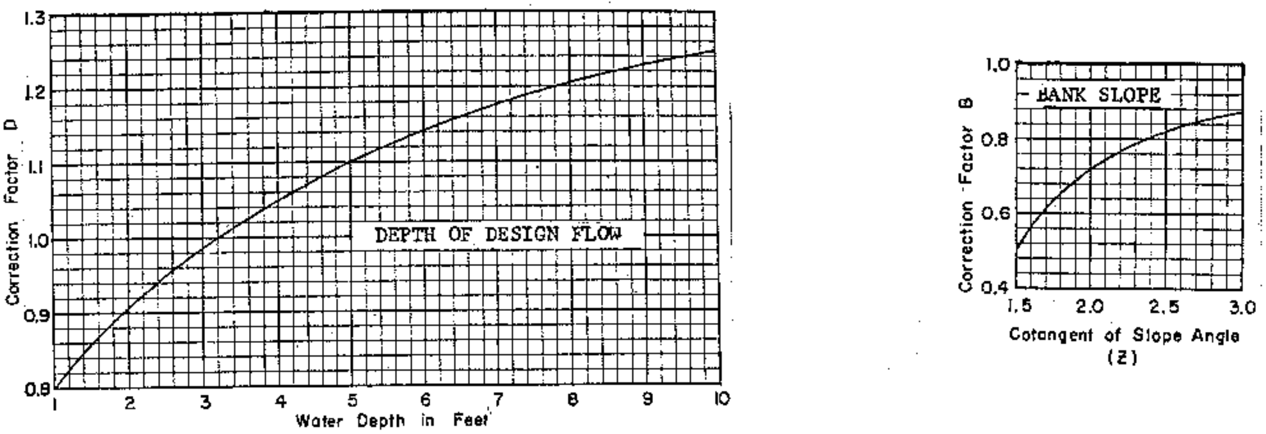
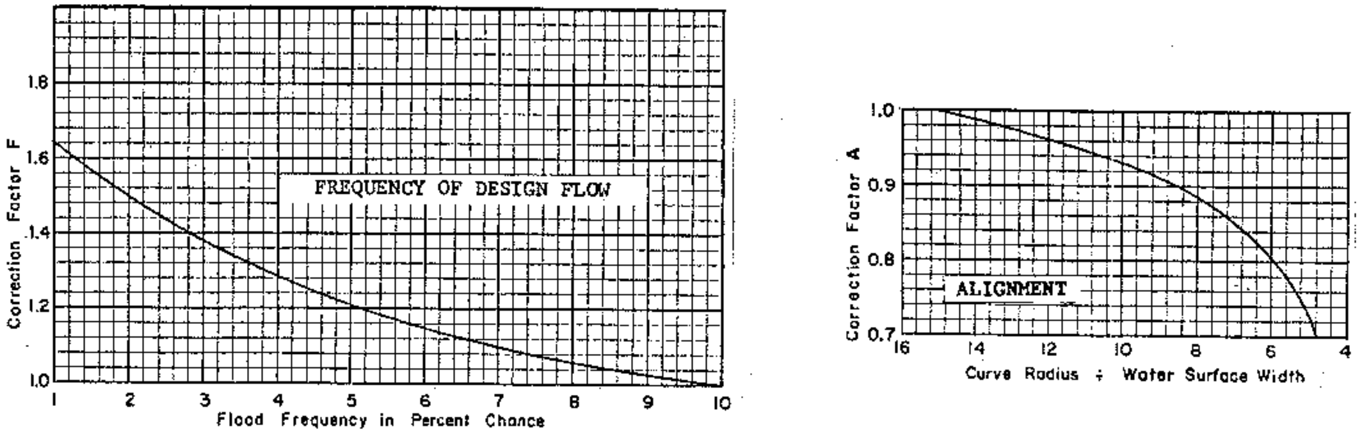


9a. Depth Correction Factor

9b. Bank Slope
Correction Factor



9c. Frequency Correction Factor

9d. Alignment Correction Factor

Tractive Force Method

The tractive force is the force that the flowing water exerts on a soil particle that tends to pull the particle free of the soil, hence causing erosion. The Tractive Force Method compares the tractive force exerted by the water flowing in the channel to the tractive force needed to dislodge a soil particle. If the tractive force exerted by the water exceeds the force needed to dislodge a soil particle, then erosion will occur. The methods used to calculate the tractive force used here were developed by Lane and suggested by SCS in Planning and Design of Open Channels. According to SCS, good results have been obtained when the Tractive Force Method is used on coarse grained non-cohesive soils. However, these criteria can be used for fine grained cohesive soils only with great caution. The method is described below in two steps:

1. Tractive Force Exerted by Flowing Water

The following discussion summarizes the steps used by Lane to develop an equation for the tractive forces exerted by flowing water. The first step was to determine a value for the portion of Manning's roughness coefficient "n" resulting only from the roughness of the soil grains. This portion of Manning's "n", called "nt", is

$$(3) \qquad n_t = \frac{(D_{75})^{1/6}}{39}$$

Where:

n_t = portion of Manning's "n" due to soil grain roughness

$D75$ = grain size of which 75 percent of soil sample is smaller (inches)

A study done by Woodward-Lundgren and Associates on factors influencing erodibility of soils in unlined earth channels noted that extrapolation of this relationship to soils with D_{75} less than .25 inches produces unrealistically low values of n_t. For example, in channels without vegetation the impedance to flow due to soil friction can be calculated to be as low as 30 percent of the total impedance, which is an unrealistic value. Therefore, as a limiting value it is recommended that nt used to calculate developed tractive forces should not be less than 85 percent of the total Manning's "n" used for channel design. The energy gradient of the flow is expressed by the normal uniform flow equation:

(4) $S_f = n^2V^2/2.208\ R^{4/3}$,

Where:

S_e = energy gradient of the flow
n = Manning's roughness coefficient
V = average cross-sectional velocity
R = hydraulic radius

The portion of the energy gradient (or the unit energy loss) caused by the roughness of the soil grains is

(5) $S_t = S_e\ (n_t/n)^2$

Where:

S_t = portion of the energy gradient caused by soil grain roughness
S_e = energy gradient of the flow
n_t = portion of Manning's "n" due to soil grain roughness
n = Manning's roughness coefficient

The tractive force on a soil grain is related to the energy loss as the water passes over it as follows:

(6) $T = \gamma_w d S_t$

Where:

T = Tractive force in an infinitely wide channel
γ_w = Unit weight of water
d = Depth of flow
S_t = Portion of energy gradient caused by soil grain roughness

The actual tractive force on the sides and bottom of the channel, T_S and T_B respectively, are determined using the graphs in Figure 10 which gave T_S/T and T_B/T as functions of b/d and z (width b, depth d and side slope z).

Since n_t tends to be underestimated for fine-grained soils, T tends to be underestimated as well, resulting in overestimation of T and T_B. In other words, if D_{75} is less than 0.25 inches, this method will overestimate the tractive force exerted by the water and, therefore, overestimate the potential danger of erosion. Since this method overestimates the problem, it can be used for fine grained soils because it automatically introduces a safety factor into the analysis. However, the fact that erosion problems can be overstated for fine-grained soils should be borne in mind when this method is used. The method gives best results for coarse non-cohesive soils.

2. Maximum Non-Erosive Tractive Force

Once the actual tractive force is known, it can be compared to the maximum non-erosive tractive force to determine if a potential for erosion exists. If the occurring tractive force exceeds the maximum non-erosive tractive force erosion may occur. The maximum non-erosive tractive force is a property of the soil. The procedure for calculating it for various soils are outlined below.

A. Coarse, Non-Cohesive Soils

Lane found that for coarse non-cohesive soils the maximum tractive force that can be exerted on the sides and bottom of a channel, T_{LS} and T_{LB} respectively, without causing erosion are

(7) $T_{LB} = 0.4\ D_{75}$

$T_{LS} = 0.4\ K\ D_{75}$

Where:

$0.25'' < D_{75} < 5.0''$

FIGURE 10

ACTUAL MAXIMUM TRACTIVE FORCES

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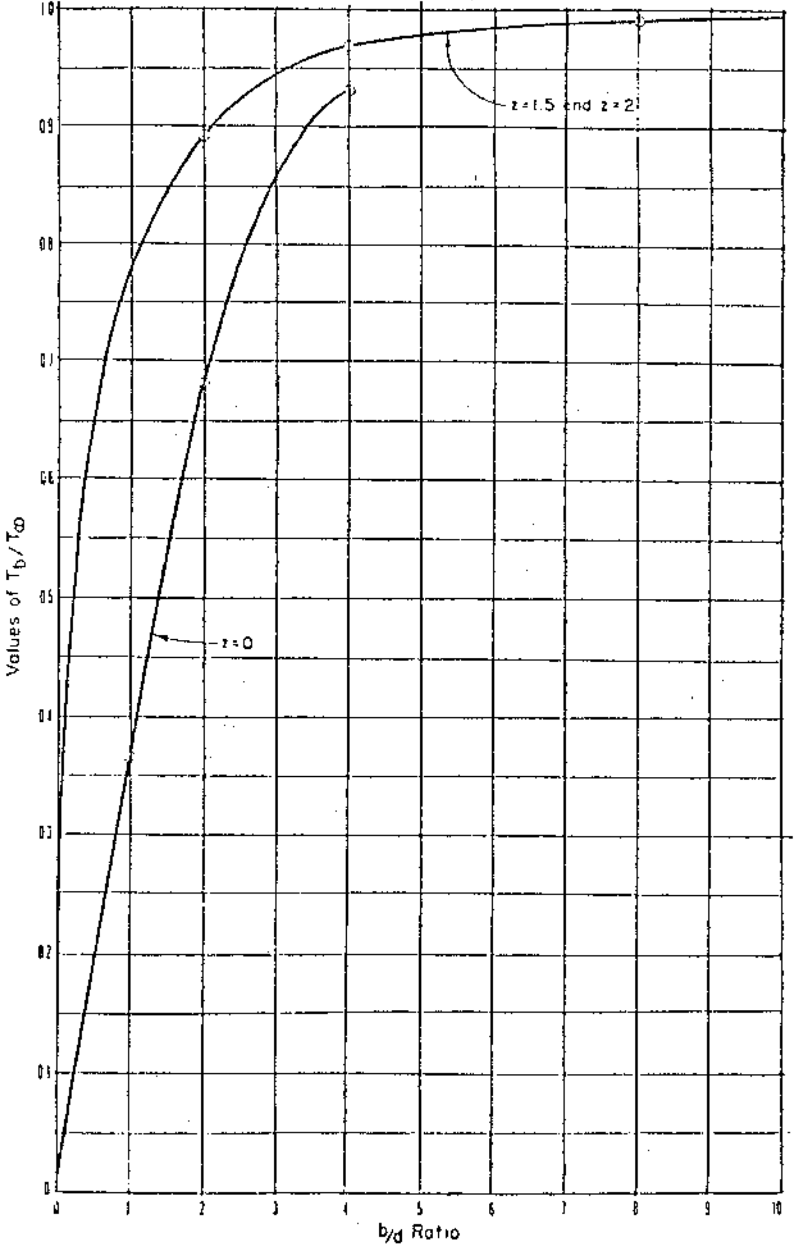
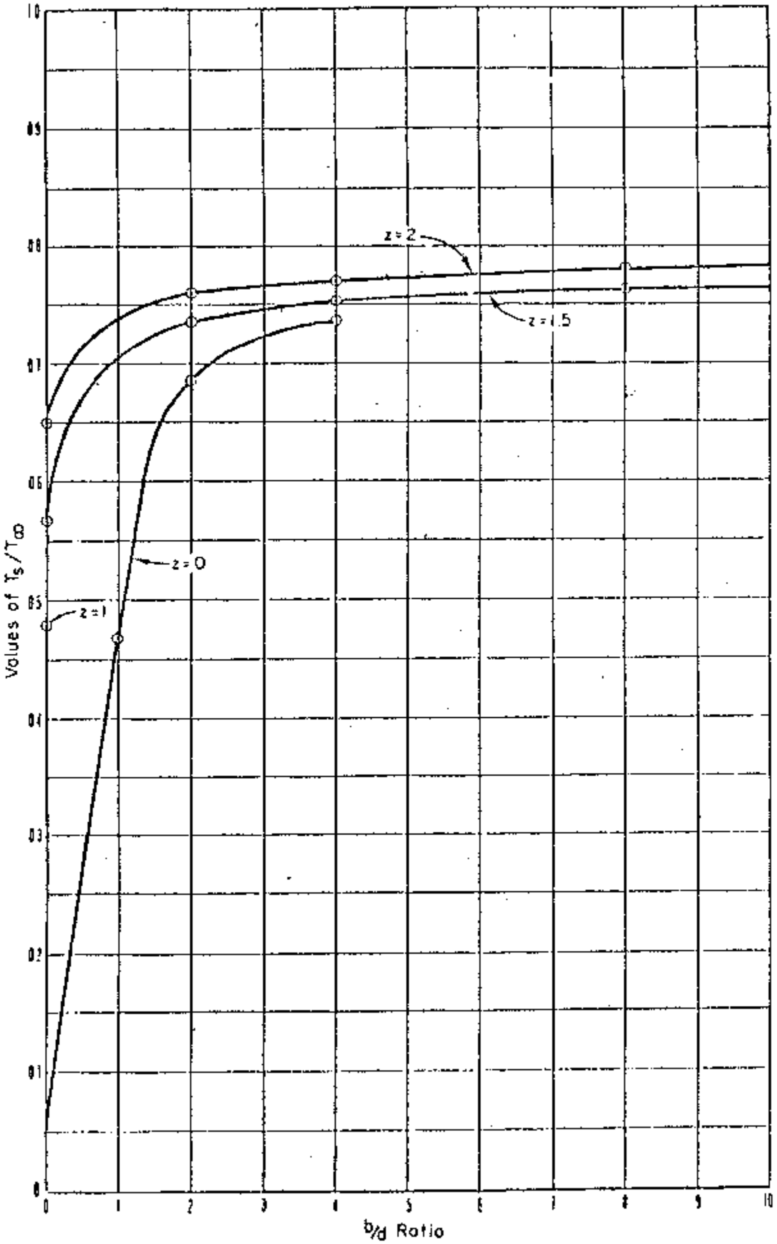


10a. Actual Maximum Tractive Force, T_B, on Bed of Straight Trapezoidal Channel



10b. Actual Maximum Tractive Force, T_S, on sides of Straight Trapezoidal Channel

(8) $$K = \frac{z^2 - \cot^{2}\emptyset}{1 + z^2}R$$

z = cotangent of side slope angle

ØR = angle of repose of soil (from Figure 11)

B. Fine Grained Soil

The maximum non-erosive tractive force for fine grained soils (D75 0.25) can be estimated from curves presented in Figure 12 which were developed by Lane. The curves, Figures 12a and 12b, are for non-cohesive and cohesive soils, respectively. Note that the grain size Figure 12a is for the D_{50} grain size.

Examples

Following are three examples of how to use the above-described methods for predicting erosion potential. The examples are for coarse grained non-cohesive soils, for fine-grained, non-cohesive soils and for fine-grained, cohesive soils. For each example erosion potential is computed by both the tractive force and the allowable velocity method.

FIGURE 11

ANGLE OF REPOSE OF SOIL PARTICLES VS. D_{75}

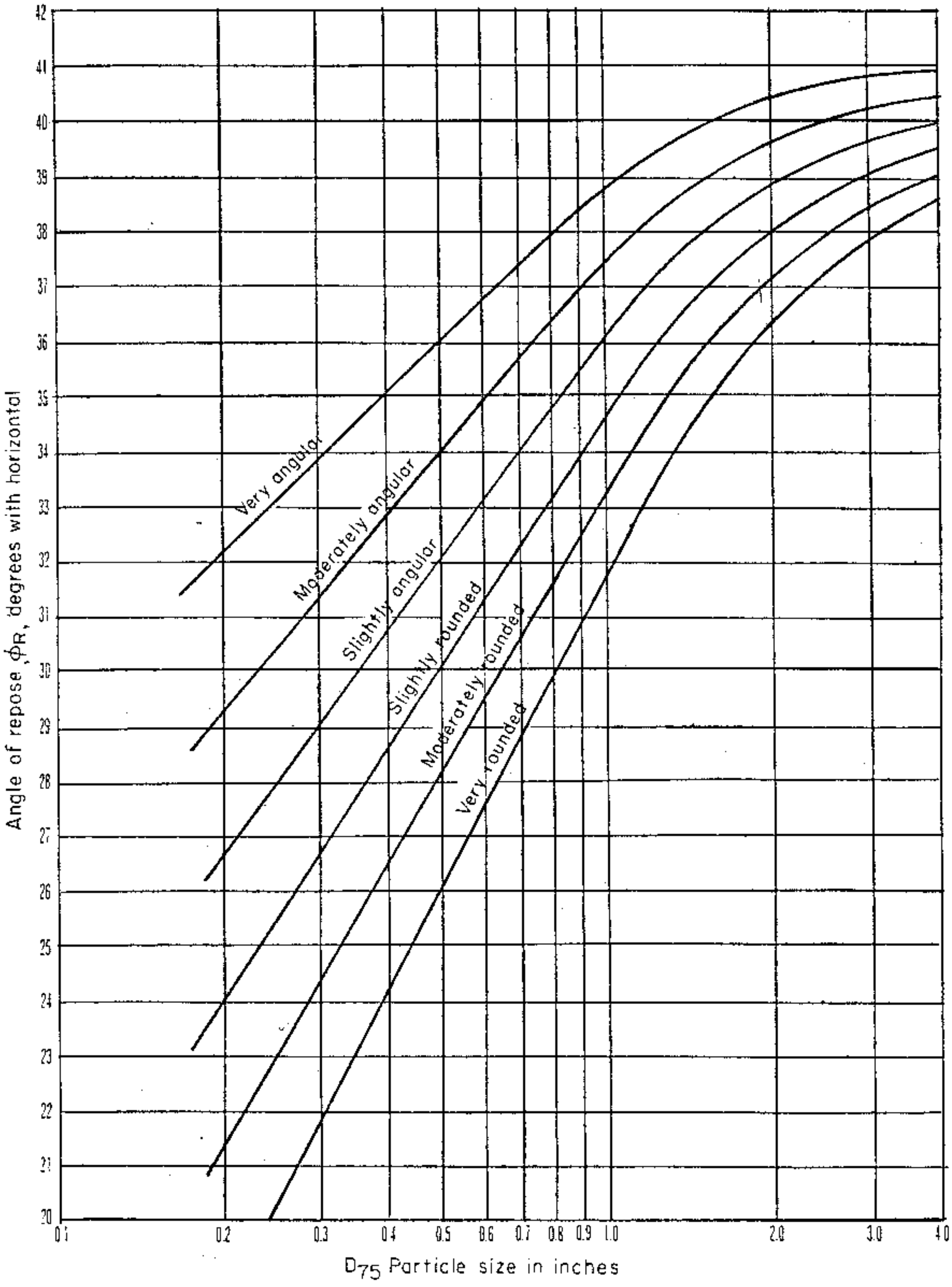
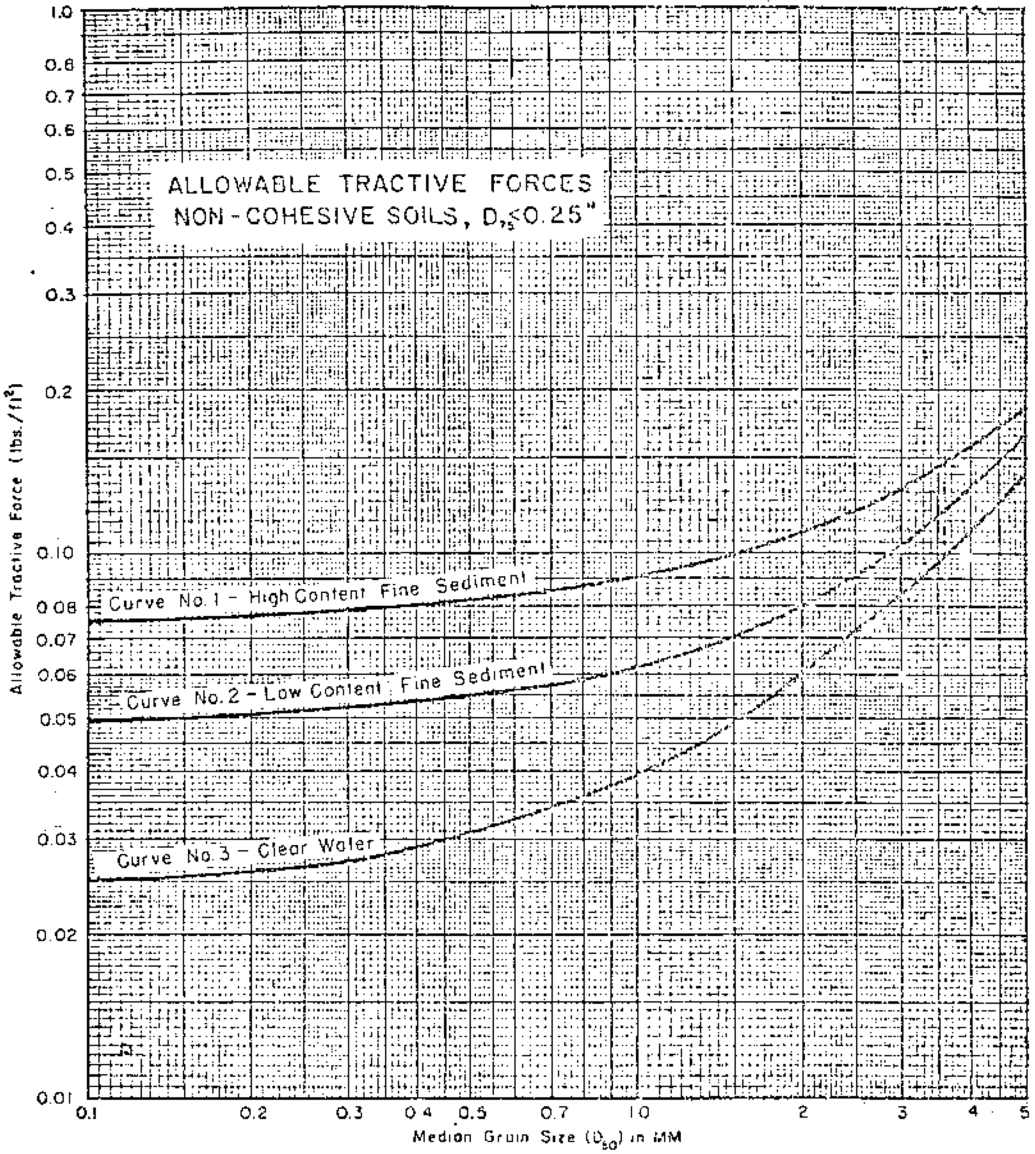
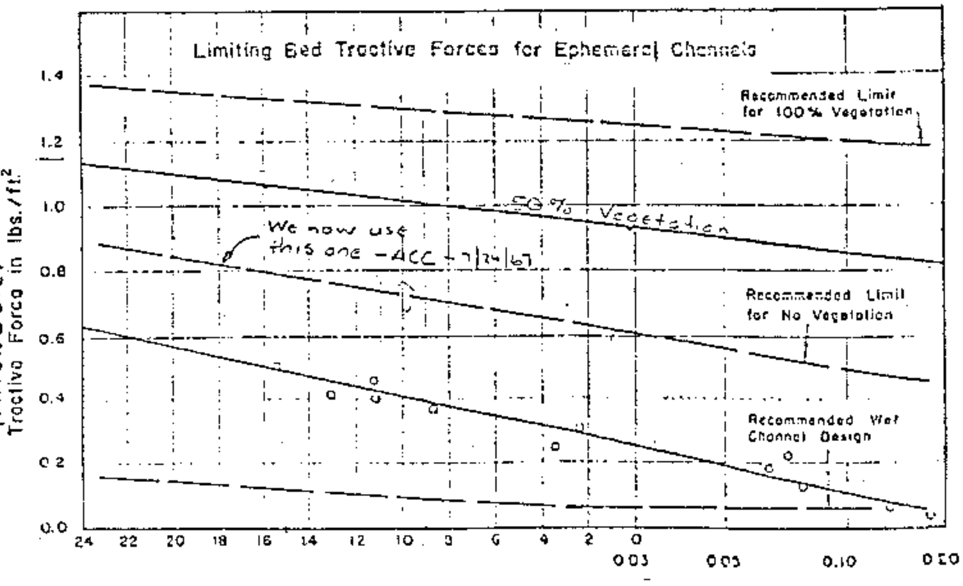


FIGURE 12



12a. Maximum Non-Erosive Tractive Force Non-Cohesive Soils



12b. Cohesive Soils

EXAMPLE 1. COARSE-GRAIN NON-COHESIVE ($D_{75} > 0.25''$)

Tractive Force Method

Given: Natural Channel
Soil type = GaA

Field Observation:
$b = 15$
$z = 2$
Manning's "n" = .04
Erosion = Non Eroding

From FIA:
W. S. Elev. = 400
Min. Bank Elev. = 392
Channel Q = 550 cfs

From S.C. County Soil Chart:
GaA = GP (Sand & Gravel)
$D_{75} = 3/8''$
$D_{50} = \#200$
P.I. = N.P.

Compute Actual Tractive Force

Determine n_t - roughness of soil grains only

$$n_t \quad \frac{(D_{75})^{1/6}}{39} \quad \frac{(.375)^{1/6}}{39} = .0218$$

Determine s_e

$$s_e = sf = \frac{n^2V^2}{2.208\ R^{4/3}} = \frac{(.04 \times 2.22)^2}{2.208\ (8.287)} = .000431$$

Determine s_t, the energy gradient caused by the soil grains

$$s_t = \left[\frac{n_t}{n}\right]^2 s_e \qquad (5)$$

Substituting $n = 0.4$ & n_t & s_e from above in Eq. 5

$$s_t = \frac{(.0218)^2}{(.04)^2}\ (.000431) = .000128$$

Determine T_∞, the unit force acting to dislodge the soil grains

$$T_\infty = \gamma_w\, d\, s_t \qquad (6)$$

Substituting $d = 8$ and s_t from above in Eq. 6

$$T_\infty = (62.4)\ (8.0)\ (.000128) = .0639 \text{ psf.}$$

Then from Figure 10a with $\frac{b}{d} = 1.88$ & $z = 2$, $\frac{Tb}{T_\infty} = .88$ and

$T_b = .88\ (.0639) =$ .056 psf

Similarly with from Figure 10b $\frac{Ts}{T_\infty} = 0.76$ and

$T_s = .76\ (.0639) =$ .049 psf.

Compute Allowable Tractive Force

Since $D_{75} \quad 0.25''$

and $T_{Ls} = 0.4\ D_{75}$ (7)

Using Figure 11 the angle of repose $\phi_R = 28.1°$ for slightly rounded gravel. Substituting this value in Eq. (8)

$$K = \frac{z^2 - \cot^2\phi_R}{1 + z^2} = \frac{(2)^2 - (1.873)^2}{1 + (2)^2} = 0.314$$

And the value of Eq. (7) is

$T_{Ls} = (.314)(.15) = .047$ psf

Actual $T_b = .056$ psf Allowable $T_{Lb} = 0.15$ psf and
Actual $T_s = .049$ psf Allowable $T_{Ls} = .047$ psf

The actual Tractive forces are within the allowable limits - Therefore the reach is STABLE by this analysis.

Allowable Velocity Method

Compute Actual Velocity "V":

d = 400-392 = 8" or d found from FIA Water Surface Profile

$$V = \frac{Q}{A} = \frac{550}{8(15)+2(8)^2} = 2.22 \text{ fps}$$

Compute Allowable Velocity "V_a":

$$V_a = VDB \qquad (1)$$

For coarse-grain non-cohesive with D_{75} = 3/8" = 9.53 mm, V = 5.2 from Figure 8, D = 1.2 from Figure 9a for d = 8' and B = 0.72 from Figure 9b for z = 2. Substituting above values in Eq. (1):

$$Va = (5.2)(1.2)(0.72) = 4.49 \text{ fps.}$$

Actual velocity V = 2.22 fps allowable velocity Va = 4.49 fps

∴ Channel is STABLE by this method.

RESULTS

Method	Actual	Allowable (Suspended Load)	Remarks
Allowable Velocity Method	2.22 fps	4.49 fps	Channel is stable
Tractive Force Method	0.056 psf	0.15 psf	bottom - stable
	0.049 psf	0.047 psf	sides - critical

***CONCLUSION:

This reach is generally stable based on above results - except that the tractive force analysis indicates the sides to be critical -

EXAMPLE 2. FINE-GRAIN NON-COHESIVE ($D_{75} < 0.25''$)

Tractive Force Method

Given: Natural Channel
Soil type = CoB

Field Observation:
$b = 115$
$z = 2$
$n = .03$
Erosion = Non-eroding

From FIA:
W.S Elev. = 314.0
Min Elev. = 300.3
Channel Q = 15,000 cfs

From S.C. County Soil Chart:
CoB = SM (gravelly sandy loam)
$D_{75} = \#4 = 0.1874''$
$D_{50} = \#10$
P.I = N.P.

Compute Actual Tractive Force:

Determine n_t = roughness of soil grains only

$$n_t = \frac{(D_{75})^{1/6}}{39} = \frac{(.1874)^{1/6}}{39} = .0194$$

Determine s_e = slope of energy gradient

$$s_e = s_f = \frac{n^2 V^2}{2.208 R^{4/3}} = \frac{(.03 \times 7.7)^2}{2.208 (24.66)} = .0098 = .001$$

Determine s_t = Energy gradient for tractive force

$$s_t = \frac{n_t^2}{n^2} s_e = \frac{.0194^2}{.03^2} (.001) = .000418$$

Fine-grain non-cohesive (cont'd)

Determine T_∞ tractive force in an infinitely wide channel

$$T_\infty = \gamma_w d s_t \qquad (5)$$

Substituting d = 13.7 and s_t from above in Eq. (5)

$$T_\infty = (62.4)(13.7)(.000418) = 0.357 \text{ psf}$$

Then from Figure 10a with $\frac{b}{d} = 8.39$ and $Z = 2$, $\frac{Tb}{T_\infty} = .99$ and

$$T_b = .99 (.357) = 0.353 \text{ psf.}$$

Similarly from Figure 10b $\frac{Ts}{T_\infty} = 0.78$ and

$$T_s = 0.78 (.358) = 0.278 \text{ psf}$$

Compute Allowable Tractive Force

Since $D_{75} < 0.25''$ compute allowable tractive forces using Figure 11a

$$D_{50} = \#10 = 2.0 \text{ mm}$$

$T_L = 0.11$ psf from Figure 12a Curve #1 (High Sediment)

Actual $T_s = 0.278$ psf and $T_b = 0.353$; allowable $T_L = 0.11$ psf

Actual tractive forces have exceeded the allowable limits, therefore, the channel is POTENTIAL - i.e. the channel has the potential to erode during flood flows although it appears stable.

Allowable Velocity Method

Compute Actual Velocity "V":

$$d = 314.0 - 300.3 = 13.7'$$

$$V = \frac{Q}{A} = \frac{15{,}000}{13.7\ (115) + 2\ (13.7)^2} = 7.7 \text{ fps}$$

Compute Allowable Velocity "V_a":

$$V_a = VDB \qquad (1)$$

For fine-grain non-cohesive with D_{75} = #4 = 4.76 mm = .1874", V = 4.4 from Figure 8, D = 1.32 from Figure 9a with d = 13.7', B = 0.72 from Figure 9b with z = 2. Substituting above valves in Eq. (1):

$$V_a = (4.4)\ (1.32)\ (0.72) = 4.18 \text{ fps}$$

Actual Velocity V = 7.7 fps V_a = 4.2 fps

. . Channel is POTENTIAL by this method, i.e. analysis indicates that velocities will be erosive during flood flows though channel appears stable

RESULTS

Method	Actual	Allowable (Suspended Load)	Remarks
Allowable Velocity	7.7 fps	4.2 fps	Potentially erosive
Tractive Force	0.28 psf	0.11 psf	Potentially erosive

***CONCLUSION:

Both analyses indicate this reach to be potentially erosive under high flows.

EXAMPLE 3. FINE-GRAIN COHESIVE

Tractive Force Method

Given: Ross Creek, between Cherry & Jarvis
Soil type = P_pA

Field Observation:
$b = 13$
$z = 1.5$
$n = .025$
Erosion = Moderately active erosion

From FIA:
W.S Elev. = 172.4 (Sta 38+19 - Nolte Run)
Min Elev. = 163.2
Channel Q = 1200 cfs
Frequency = 10%

From S.C. County Soil Chart:
P_pA = ML or CL (Loan or gravelly clay loam)
D_{75} = #40 = .0165"
D_{50} = #200
PI = 11-20

Compute Actual Tractive Force

Determine n_t = roughness of soil grains only

$$n_t = \frac{(D_{75})^{1/6}}{39} = \frac{(.0165)^{1/6}}{39} = .0129$$

Determine s_e = slope of energy gradient

$$s_e = s_f = \frac{n^2V^2}{2.208\ R^{4/3}} = \frac{(.025 \times 4.8^2)}{2.208\ (9.33)} = .008 = .00214$$

Determine s_t = energy gradient for tractive force

$$s_t = \frac{{n_t}^2}{n^2}\ s_e = \frac{.0129^2}{.025^2}\ .0008 = .000214$$

Determine T_∞ = Tractive force in an infinitely wide channel

$$T_\infty = \gamma_w d s_t = (62.4)\ (9.2)\ (.000214) = 0.123 \text{ psf}$$

Fine Grain Cohesive (cont'd)

Then from Figure 10a with $\frac{b}{d} = 1.41$ and $2 = 1\text{-}1/2$, $\frac{Tb}{T_\infty} = 0.84$ and

$$T_b = .084\ (.123) = .103 \text{ psf}$$

Similarly from Figure 10b, $\frac{Ts}{T_\infty} = .725$ and

$$T_s = .725\ (.123) = .089 \text{ psf}$$

Compute Allowable Tractive Force

Since the soil is cohesive fine-grain use Figure 12b to compute allowable tractive force.

T_{Lb} = 0.1 psf for PI=11 from Figure 12b.

Actual Tractive force $T_b = 0.1$ = Allowable $T_{Lb} = 0.1$ psf - Critical

Allowable Velocity Method

Compute Actual Velocity "V":

From FIA:
V = 4.78 fps (for Sta 38+19)
or: d = 172.4 - 163.2 = 9.2'

$$V = \frac{Q}{A} = \frac{1200}{9.2\ (13) + 1.5\ (9.2)^2} = 4.9 \text{ fps}$$

Compute Allowable Velocity "V_a":

$$V_a = VDF \qquad (1)$$

For fine-grain cohesive with soil group ML or CL & PI = 11-20, V = 4.0 fps from Figure 8 for suspended load, D = 1.23 from Figure 9a with d = 9.2' and F = 1.00 from Figure 9c since frequency is more than 10%.

Note: If channel is inadequate to carry the design flow then the frequency correction should be based on whatever frequency the bankful flow corresponds to.

Substituting above values in Eq. (1)

Va = (4.0)(1.23)(1.00) = 4.91 fps

Actual Velocity V = 4.9 fps = Allowable Va = 4.9 fps

. . Channel is in critical condition

RESULTS

Method	Actual	Allowable (Suspended Load)	Remarks
Allowable Velocity	4.9 fps	4.9 fps	Critical
Tractive Force	0.1 psf	0.1 psf	Critical

***CONCLUSION:

Both analyses indicate channel is in critical condition and erosion is probable.

References

1/ "Planning and Design of Open Channels", U. S. Department of Agriculture Soil Conservation Service, Technical Release No. 25, December 15, 1964.

2/ Fortier, S. F. and Scobey, F. C. - "Permissible Canal Velocities"; ASCE Trans. 89, p. 940-956.

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CHAPTER 4
SEDIMENTATION

The purpose of this chapter is to document how estimates of sediment generation have been made. The methodology is applied using a computer program developed as part of the Waterways Planning Study. The input requirements and output available are described in detail in the Users Manual.

Several methods were considered; the references discussing these methods are listed at the end of this chapter. Most were rejected because of the data requirements. For instance, the regression equation developed for Colma Creek Basin (Reference 3) might be appropriate for estimating sediment yield in Santa Clara County creeks because of some similar geologic and geographic characteristics. However, the equation required more detailed knowledge of land use than we have available at this time (e.g. acres in watershed currently under construction). Despite the shortcomings of the method finally selected and described below, it produces relatively good results compared with actual data and other estimates, and it does not require the development of new data.

Methodology

Sediment yield is calculated from a regression equation developed by Henry Anderson of the Forest Service, U. S. Department of Agriculture in 1949 (Reference 1).

$$Y_s = 11.0 \times \frac{q^{0.87} a^{0.37}}{C^{1.24}}$$

Where:

Y_s = total annual sediment yield (acre-feet/square miles)

DA = drainage area (square mile)

A = area of main channel including area of main channel tributaries and excluding those reaches which are lined (acres)

a = A/DA (acres/square mile)

Q = annual peak flowrate (cfs)

q = unit flowrate = Q/DA (cfs/square mile)

C = percentage of ground protection, loosely related to ground cover; varies from 1 (no protection) to 100 (totally protected).

According to Anderson's equation, the annual volume of sediment (sedimentation yield) which could be collected at a station in the channel is a function of:

a) the ratio of area of the channel upstream of the station to the drainage area upstream of the station;

b) the ratio of the annual peak flowrate past that station to the drainage area;

c) the percent of ground which is protected from erosion by vegetation;

d) a "constant" coefficient which varies with geology and soil type.

Following is a discussion of each element of Anderson's equation.

Coefficient

Anderson's regression equation was developed using data from watersheds located on the South facing slopes of the San Gabriel and San Bernardino Mountains of Southern California. The watersheds were characterized by steep topography, highly fractured igneous and metamorphic rock; shallow, coarse-textured soils mostly less than three feet deep; and vegetation varying from sage on lower, drier sites to mixed chaparral, oak-chaparral and conifers on higher, less dry sites. Channels were essentially unlined and watersheds undeveloped.

There are major differences between watershed conditions in the Santa Clara Valley and those used to develop Anderson's equation. Geology within Santa Clara County is varied and watershed composition may change drastically from one creek to another. Local geology includes the very old, highly fractured and sheared Franciscan Formation; the folded and bedded conglomerate, sandstone, siltstone and mudstone, of the Santa Clara Formation; the alluvial fan and marine sediment deposits of the lower elevations; and other geologic zones. Soil types and depths, topography and vegetation vary as well with the geology which underlies them.

In a personal communication, Anderson noted that the coefficient in his equation varies with geologic type. For instance, with marine sediments, the constant generally is about 5.5 instead of 11.0. The constant which produces the best results, when compared with existing sediment data from Santa Clara County watersheds, is 2.5.

Percent Ground Cover

The cover factor is an estimate of what percentage of the watershed has effective protection from surface runoff, and hence, from erosion. In the original analyses of undeveloped watersheds, cover was related to the density and age of forests and ranged from 30 percent for recently burned areas to 75 percent for mature vegetation. In the developed watersheds of Santa Clara County some areas are covered by pavement, buildings and lawns from which there is virtually no erosion. Therefore, in urban areas the cover factor usually exceeds 75 percent. Exposed soil areas, such as construction sites and plowed agricultural land, greatly increase sediment production and reduce the cover factor.

A comparison was made between actual sediment yield data from a USGS station on Calabazas Creek at Rainbow Drive and the results of Anderson's equation when different cover factors are assumed (Figure 13). A cover factor of 70 percent resulted in predicted values of sediment yield which approximate fairly well the actual sediment yield data. Calabazas Creek watershed had the following characteristics at the time the USGS compiled its sediment data:

Rangeland and forest	47%
Orchards and vineyards	35%
Cropland or pasture	10%
Urban area	6%
Golf course, small ponds, gravel pits	2%

Because of the rural nature of the watershed and exposed soil areas in orchards and vineyards, a low cover factor is expected and the 70 percent cover factor calculated seems reasonable. However, a quarry is located on one of the upstream tributaries which the USGS estimates "transports eight or nine times as much sediment per square kilometer as other upstream tributaries." In view of this, 70 percent seems a little high but still within the range of credibility.

FIGURE 13

COMPARISON OF RESULTS OF ANDERSON'S EQUATION WITH DATA FROM CALABAZAS CREEK TO DETERMINE COVER FACTOR

Data from Calabazas Creek (USGS Station No. 11169616 - Rainbow Drive)

Drainage Area = 3.97 sq. mi. = DA
Area of Main Channel[1/] = 17.9 acres = A
Unit Area = 4.51 acres/sq/mi. = A/DA

Rainfall and Sediment Data

Year	Peak Annual Flow (cfs)	Sediment Yield[2/] (acre-feet/sq mi)	Unit Flow cfs/sq mi
1974	289	0.98	72.8
1975	650	1.85	164.0

Results Using Anderson's Equation

$$Y_s = 2.5 \frac{q^{0.87} a^{0.37}}{C^{1.24}} \quad \text{in acre feet/sq mi}$$

Year	Unit Flow cfs/sq mi	Sediment Yield Calculated, Y_s Using Cover Factor Shown			Actual Sediment Yield	"Best" Cover Factor (By Interpolation)	
		60	70	80			
1974	72.8	1.14	0.94	0.79	0.98	67	69
1975	164.0	2.30	1.90	1.61	1.85	71	

Calabazas Creek watershed is not a typical rural Santa Clara Valley watershed due to the quarry located there. However, there is no sediment data from a watershed, rural or urban, which is "typical" of the South Bay area. Data exists on Coyote, San Francisquito, Uvas and Pacheco Creeks in upstream, undeveloped watersheds, and on Calabazas and Colma Creeks where special conditions (e.g. a quarry or extensive construction and land development) create significant sediment problems. This makes testing and calibration of any analytical method or formulation of a more appropriate local regression equation difficult.

Unit Flow

Unit flow is defined as the annual peak flowrate from a drainage basin divided by the area of that basin. Drainage basin areas were obtained from the District's "Design Flood Flows Manual", January 11, 1979 prepared by A. Saah (Reference 7). Existing one and ten percent flowrates determined from the FIA studies and the Design Manual were used to examine the range of annual sediment yields and estimate an average annual sediment yield based on the fifty percent flowrate.

Anderson's equation estimates annual sediment yield based on the annual peak flow rate. It does not take into account how many higher frequency storms occur during the year or, for instance, if three peak flow rates of the same magnitude occur in one year. If multiple regression analyses of sediment data in Santa Clara County were to be done, the mean annual flow rate, together with the peak annual flow rate, might result in a better index of annual sediment production.

Unit Channel Area

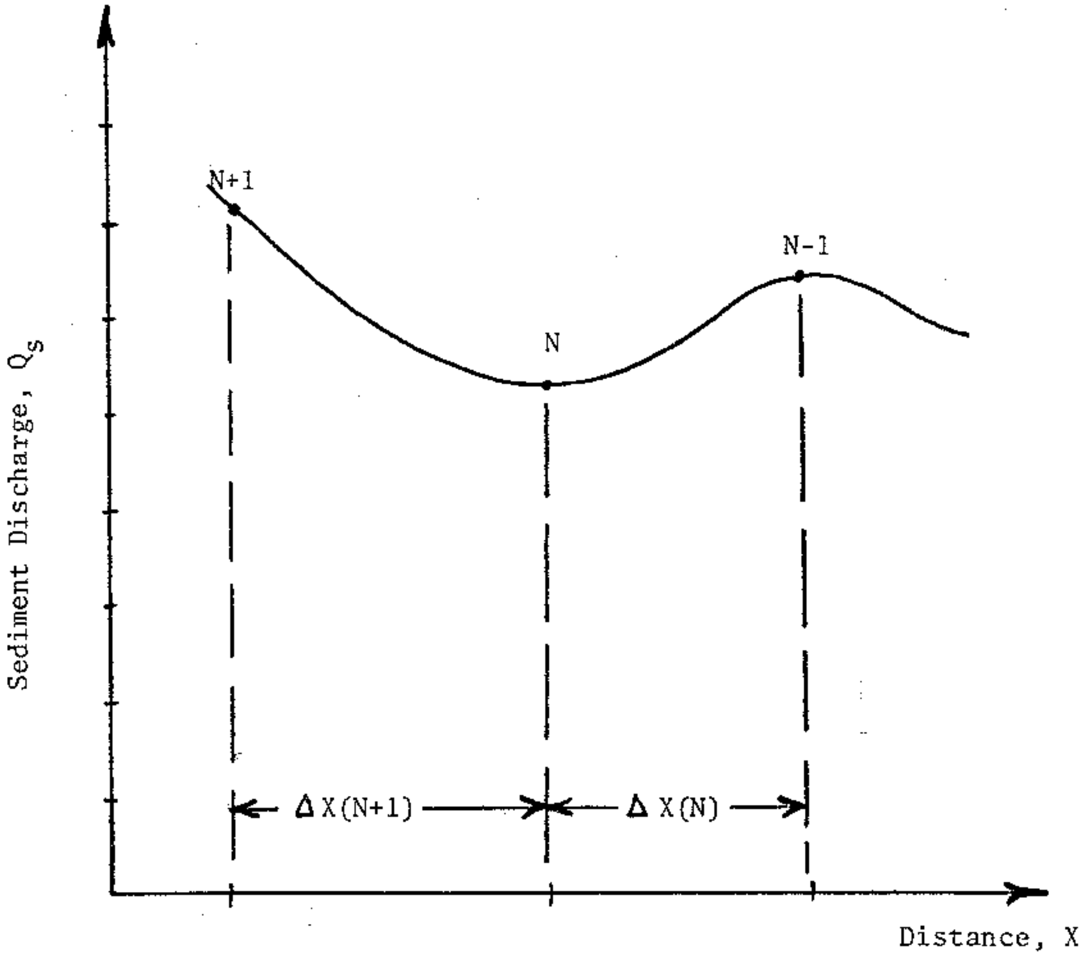
Unit channel area is the area of unlined channel in a drainage basin divided by the basin area. The area of unlined channel is computed by multiplying the length of each reach of channel by the top width of the channel in that reach. If the 100-year flowrate is contained in the channel, the width of this water surface is the top width used.

Results

Unit and volumetric sediment yields are calculated for two annual peak flow rates: one equal to the existing one percent flow rate, and one equal to the 50 percent flow rate. The 50 percent (or 2-year) result is intended to be used as an estimate of average annual sediment yield. For example, the average annual sediment yield calculated for Berryessa Creek at Sierra Creek confluence is 0.7 acre-feet/square mile and for Upper Penitencia Creek at Dorel Drive is 0.3 acre-feet/square mile. These are considered reasonable values, compared to other estimates of average annual sediment yield in similar watersheds. For example, the District estimated in 1973 an annual deposition rate of 0.4 acre-feet/square mile for Silver Creek tributaries, based on data from San Francisquito Creek and North Fork Reservoir on Pacheco Creek. The estimate made by SCS for Silver Creek varied from 0.5 to 2.5 acre-feet/square mile, based on the Universal Soil Loss Equation.

At present a rough estimate of average annual sediment deposition depth is made by uniformly distributing differences in average annual sediment yields over each reach. For instance, if three cubic yards/year are produced at upstream Station (N+1) and two cubic yards/year are produced at downstream Station (N), the difference, one cubic yard must be deposited somewhere in the reach between Station (N+1) and Station (N), causing channel aggradation. This volume is distributed uniformly over the channel bottom in that reach. On the other hand, if sediment yield increases between the upstream and downstream stations then channel degradation has occurred, and the loss is distributed uniformly over the reach (See Figure 14). In the long run, channels tend to establish a dynamic equilibrium with uniform sediment discharge such that the channel neither degrades nor aggrades.

A better estimate of sediment deposition could be made if flow velocities are known. Velocity information is available in the Corps of Engineers' Water Surface Profile Program (HEC-2). Sediment removal information from Maintenance Division



Deposition or aggradation is occurring in ΔX(N+1).

Scour or degradation is occurring in ΔX(N).

FIGURE 14

SEDIMENT DISCHARGE RELATION TO AGGRADATION AND DEGRADATION OF CHANNELS records may be useful in verifying whether average annual sediment deposition estimates are reasonable.

Conclusions

In view of the purpose of this program to provide relative sediment yield information, Anderson's equation is considered suitable. The aim is to find a method which, using available data, produces "ballpark" sediment production estimates that may be used for comparison purposes. Anderson's equation is seen as a starting point towards this end. Hopefully, a study using local data from representative watersheds and multiple regression techniques would produce a better equation. At this time, the data available for such a study is limited. The adequacy of existing information and the possibility of obtaining more sediment data in preparation for a study should be investigated.

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3/ "Effects of Urbanization on Sedimentation and Floodflows in Colma Creek Basin, California", J. M. Knott. U. S. Department of Interior, Geological Survey, Water Resources Division. February 1973.

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6/ "Simplified Methods for Computing Total Sediment Discharge with Modified Einstein Procedure", B. R. Colby and D. W. Hubbell. Water Supply Paper 1593, U. S. Department of Interior, Geological Survey, 1961.

7/ "Design Flows Manual", A. Saah, Santa Clara Valley Water District, January 11, 1979.

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CHAPTER 5
ENVIRONMENT

Part of the INVENTORY is a determination of what the environmental conditions are in each reach of the stream. Protection and conservation of environmental quality has become an important part of water resource management, especially with the passage of federal and State environmental laws in the early 1970's. The California Environmental Quality Act specifies that environmental impact must be assessed for public agency projects, that feasible mitigation measures must be part of public agency projects, and that protection of environmental quality shall be "the guiding criterion" for all development in the State of California. In practice, CEQA has contributed to an expanded view of how water resources should be managed, and has mandated the preservation of environmental values in the development and maintenance of waterways. Other recent legislation which has affected water resource management include: State and Federal Wetlands Policies, the Rare and Endangered Species Act and the National Historic Preservation Act.

The purpose of including environmental conditions in the INVENTORY is to identify those reaches of creeks that are environmentally sensitive to the District's stream management activities. If a stream reach has a relatively high habitat quality classification, certain stream development schemes are likely to be unacceptable and others may require costly mitigation measures. The environmental assessment for such a project also is expected to be more lengthy and costly. Maintenance activities in environmentally sensitive areas are likely to be limited by the State Department of Fish and Game, a factor to consider when designing an acceptable flood damage reduction project for the reach.

The environmental INVENTORY provides a Countywide perspective on water resources and provides a basis for assessing Countywide impacts of activities on any one creek. Groundwater recharge and recreational uses are also included in the environmental INVENTORY of each creek.

Types of Environmental Conditions

For the purposes of this evaluation procedure, habitats are the (somewhat arbitrary) divisions of vegetation commonly found in the riparian corridors of Santa Clara County. A reach of channel may include one or more types of habitat or may include no significant habitat. The habitats and types of vegetation found in each are described below:

Freshwater Marsh - Although a substantial number of plants are considered freshwater marsh species, this habitat type is dominated by a few well-known plants. These include cattails, tules, water smartweed, reeds, sedges, curly dock, spiny cocklebur, watercress, and many others.

Salt/Brackish Marsh - The salt marsh is a distinct habitat type in itself whereas brackish marsh is actually an ecotone, a transition zone between strictly salt marsh and entirely freshwater marsh. Salt marsh vegetation grows within very narrow limits, directly related to saltwater tidal inundation duration. The most common salt marsh plants found in Santa Clara County include cord grass, pickleweed, fat hen, salt grass, marsh grindelia, sea blight, and brass buttons. Brackish marsh may also be composed of some of these plants, but are often dominated by other species such as tules, bulrushes, and cattails.

Grassland - True native grassland habitat is relatively rare in most of the County. The term "grassland", as used here, refers primarily to areas dominated by the most common herbs, grasses and weeds. These plants have largely been introduced by western man within the last 200-300 years from other parts of the world, generally from Europe. They include wild oats, Italian rye grass, bromes and other grasses, sweet fennel, poison hemlock, milk thistle, field and black mustards, and many other common weeds.

Oak Woodland - This habitat is often found either intergrading with riparian or as a remnant remaining in association with the riparian habitat following land development of the surrounding area. Plant species common to this type include valley oak, coast live oak, blue elderberry, poison oak, California buckeye, common snowberry, and California wild rose.

Riparian - The most common species associated with this habitat type include california bay, California blackberry, Western sycamore, white alder, black walnut, Fremont and black cottonwood, Pacific (yellow), red, and arroyo willows, bigleaf maple, California boxelder, and virgin's bower.

Assessment of Existing Environmental Conditions

The purpose of the inventory of environmental conditions is to identify those areas that have significant environmental resources. Two rough scales were developed: one for quantity of vegetation and one for quality of wildlife habitat.

Quantity of Vegetation

The amount of vegetation in a reach has been characterized as one of the following: none, sparse, moderate or abundant. A numerical value accompanies the characterization ranging from "1" for "none" to "4" for "abundant". The vegetation quantity designations represent amounts of vegetation relative to some ideal maximum for that habitat type. The consideration given to accommodating variations in maximum amounts of vegetation is shown in the following example: A given unit area of mature salt marsh (say one hectare) will contain less biomass than one hectare of mature riparian vegetation. Thus, it would be misleading to denote the salt marsh as having "sparse" or "moderate" vegetation, relative to the ideal mature riparian community.

Relative Habitat Quality

The quality of a habitat is measured by how well it provides the three basic requirements of all wildlife - food, cover, and water. Lack of any of these basic requirements may substantially reduce the habitat quality and, thus, the variety and numbers of wildlife present.

Food availability is an important determinant of wildlife habitat value. The quantity and variety of food plants, or plants which are secondary food sources, (e.g., plants which attract insects that are available as food) strongly influence both the variety and numbers of animals in any given habitat. This is because most animals are very choosy eaters, generally finding only a limited diet acceptable to them.

Cover is necessary to all wildlife for resting, escaping predators, and sleeping. Types of cover obviously vary with varieties of plants composing a given habitat. Usability of various plants as cover differs for different animal species; cover suitable for a red-shafted flicker may not be suitable for a raccoon for example.

Water is needed by all animals. Lack of water significantly reduces wildlife presence. Waterless habitat will likely be restricted to supporting only highly mobile creatures such as birds.

The relative habitat quality of a reach has been characterized as one of the following: very low, low, moderate, good or high. A numerical value accompanies the characterization ranging from "1" for "very low" to "5" for "high".

Multipurpose Uses

Recreation

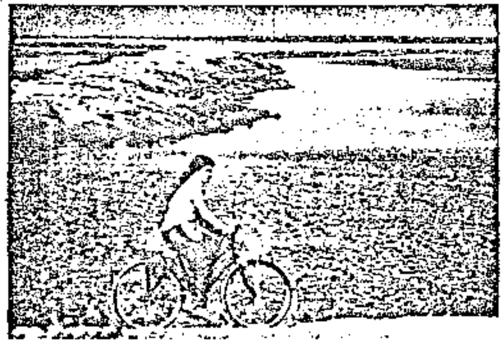
An element of the Santa Clara County General Plan provides for the eventual establishment of a system of regional parks, trails and scenic highways. Parkland and open space suitable for recreation purposes have been acquired by the County Parks Department, the Midpeninsula Regional Open Space District, the State of California, the Federal Government, various city governments and the Santa Clara Valley Water District. If a Santa Clara Valley Water District facility is currently or potentially a part of the system of regional parks and trails and, therefore, potentially part of a multipurpose cooperative project, this information is included in the environmental INVENTORY. Projects developed on stream reaches included in the regional parks and trails system must also be viewed in a narrower perspective, i.e., the least environmentally impacting alternatives are preferred. Table 12 shows some elements of the current General Plan which affect District facilities: recreational use plans for the County's baylands, streamsides and reservoirs.

TABLE 12

The Baylands

South San Francisco Bay is a scenic and recreation resource which has not always been fully appreciated. Access to the Bay is difficult except in one or two places. The Baylands have been used for dumping of sewage and garbage. Its large expanses of tidal flats are seen by some as unsightly mud. Yet, the Baylands are a unique and stimulating environment, teeming with wildlife and enjoyable in many ways. They are our County's only frontage on salt water.

Shoreline recreation should be accommodated in ways compatible with maintaining the natural habitat. The outer shore should be kept for those activities which can take place only there: enjoyment of the open water, the birds and wildlife, and boating on the open bay and the sloughs. Back from the shore there can be picnic areas and open meadows for unstructured play. Farther back yet can be areas developed for active sport -- golf courses, play fields.



1. PALO ALTO YACHT HARBOR. Existing; developed. Managed by County Parks and Recreation Department under lease from the City of Palo Alto. Has capacity of 108 berths. Adjoins Palo Alto Interpretive Center with its boardwalks to the Bay over marsh areas for wildlife observation; 92 acres.

2. PALO ALTO FLOOD BASIN. Existing. A valuable upland meadow area used by wildlife for nesting and resting. Owned by the City of Palo Alto as a flood control basin, it is a wetland in the rainy season, but is a dry meadow area most of the year. It should be preserved in its natural state so far as is consistent with flood control requirements; 600 acres.

3. CHARLESTON SLOUGH WILDLIFE PRESERVE. Existing. A tidal slough and wet marsh teeming with a variety of wildlife. It is a favorite habitat for Egrets, the Great Blue Heron, and a myriad of shore birds. Managed by the City of Mountain View; 51 acres.

4. SHORELINE PARK. Proposed. The immediate shoreline of the Bay should be acquired for public access and enjoyment. Recreation development would be consistent with the protection of the area's natural resources and maintenance of water surface areas of the Bay and adjacent salt ponds. Trail links with Mountain View Shoreline Park and the Stevens Creek Park Chain should be considered.

5. MOUNTAIN VIEW SHORELINE PARK. Existing; partially developed. A baylands park planned for a variety of recreation facilities including a sailing basin, a golf course, and playfields. Acquired and developed jointly by the City of Mountain View and Santa Clara County; 550 acres.

6. SUNNYVALE - SANTA CLARA BAYLANDS PARK. Existing; undeveloped. Part of the area is owned by the City of Sunnyvale and is being reserved under agreement with the County for later use as a regional park. Can be developed for intensive recreation activity as a Baylands Park; 280 acres.

7. SANTA CLARA VALLEY FLOOR PARK. Proposed. Site is partly owned by the City of Santa Clara for initial use as a solid waste disposal site. Low-lying flat lands along the Guadalupe River could be intensively developed and would be a major feature of the Guadalupe Streamside Park Chain.

8. ALVISO MARINA, COUNTY PARK. Existing; developed. Has berths and a launching ramp, as a first stage of development. Needs further development; 30 acres.

9. SAN FRANCISCO BAY NATIONAL WILDLIFE REFUGE. Existing. The refuge includes portions of Santa Clara, Alameda, and San Mateo counties. Within the refuge are waters of the Bay, salt ponds, marshes, and upland areas. Located along the Pacific Flyway, the refuge provides feeding, resting and nesting areas for hundreds of thousands of birds and other wildlife, including several rare and endangered species. An environmental education facility is located in Alviso. Trails, wildlife observation blinds, and other facilities for recreation use are planned.

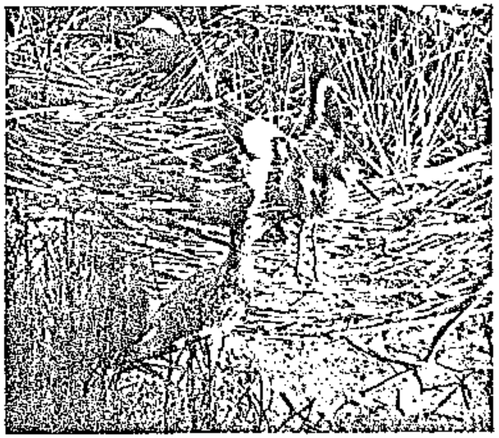
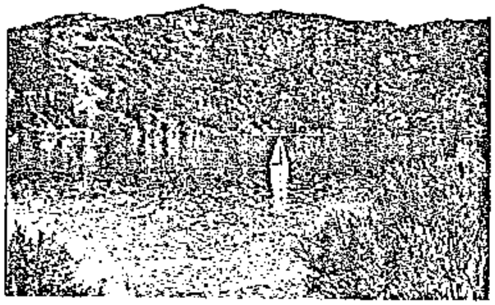


TABLE 12, continued

Reservoirs

Nestled in the folds of the hills surrounding Santa Clara County are clusters of water conservation lakes. In a semiarid country, these sizable bodies of water are refreshing and exciting to come upon. A benefit perhaps as important as the water these lakes conserve is the recreation opportunity they afford. Managed for recreational use by the County Parks Department, these lakes are heavily used for all kinds of water activities.



10. STEVENS CREEK COUNTY PARK. Existing; developed. Includes Stevens Creek Reservoir. Popular for swimming, fishing, boating and picnicking. Trail connection easement corridor proposed. There shall be no use of condemnation to acquire residences in Stevens Canyon unless specifically requested by the owner of a residence; 777 acres.

11. VASONA LAKE COUNTY PARK. Existing; developed. Perhaps the County's most popular park. Offers fishing, sail boating, row boating, canoeing, picnicking, and miniature train rides. Large lawn areas for unstructured play; 151 acres.

12. LEXINGTON RESERVOIR COUNTY PARK. Existing; partially developed. Popular in spring and early summer for fishing, motor boating, water skiing. Needs more public land for development of recreation facilities; 844 acres.

13. GUADALUPE RESERVOIR COUNTY PARK. Existing; undeveloped. Steep shoreline limits its recreational usefulness. Can be used for boating and fishing, if stocked; 107 acres.

14. ALMADEN RESERVOIR COUNTY PARK. Existing; undeveloped. A small reservoir suitable for boating and fishing; 112 acres.

15. CALERO RESERVOIR COUNTY PARK. Existing; partially developed. A large reservoir suitable for power boating and all water sports. May be enlarged to store imported water. Would then have a constant level for year-round recreation use; 2,284 acres.

16. CHESBRO RESERVOIR COUNTY PARK. Existing; undeveloped. This reservoir may be expanded. Reserved for sailing, rowing, and canoeing. Popular for fishing; 528 acres.

17. UVAS RESERVOIR COUNTY PARK. Existing; partially developed. Limited to nonpower boating. Popular for fishing when stocked. Can be a key feature of the Uvas Creek Park Chain; 639 acres.

18. PACHECO RESERVOIR PARK. Proposed. If it is determined that a reservoir can be built here, as proposed, without adverse ecological impact, provision should be made for recreational use.

19. NORTH FORK PACHECO RESERVOIR PARK. Proposed. This reservoir, administered by the Pacheco Pass Water District, should be stocked with fish and opened for recreation.

20. CANADA DE LOS OSOS RESERVOIR PARK. Proposed. If a reservoir can be built here as proposed without adverse ecological impact, it should be utilized for recreation. Plans foresee two reservoirs, one on Coyote Creek for flood control, and a smaller reservoir on de los Osos Creek for recreation purposes. The latter would have a constant water level.

21. COYOTE RESERVOIR COUNTY PARK. Existing; partially developed. A large reservoir suitable for all water sports, including fishing, power boating and water skiing. Includes flat land along the western shore. Picnicking, camping and hiking; 760 acres.

22. ANDERSON LAKE COUNTY PARK. Existing; undeveloped. This park, when developed, will make an excellent base for the enjoyment of this large reservoir, which offers all kinds of water recreation; 2,031 acres, including 383 park acres.

23. CUNNINGHAM LAKE PARK. Existing; being developed. Will include a 50-acre lake, a boat marina, swimming lagoon, fishing pier, picnic areas, and play areas. City of San Jose; 204 acres.

24. CALAVERAS RESERVOIR PARK AND ECOLOGICAL PRESERVE. Proposed. Reservoir and adjacent land owned by San Francisco Water Department. Proposed recreational use, through an agreement with the County of Santa Clara, would include picnicking, row boating, fishing on the reservoir and its close-in shoreline. Watershed areas would be kept as an ecologial preserve.

Streamsides

The streamsides of Santa Clara County are rich in beauty and recreation opportunity. The streamsides should be utilized to the fullest for their open space and recreation potential. If left in their natural state, they can give welcome relief to the buildings and pavements of the urban development which has filled most of the valley.

Streams offer the possibility of walking, riding or bicycling on bankside trails in a natural setting, safe from traffic. Some have potential for development as Streamside Park Chains -- a necklace of parks strung along a continuous streamside trail system.

49. STEVENS CREEK PARK CHAIN. Partly existing; undeveloped. City of Mountain View owns 50 acres in a strip between Stevens Freeway and Stevens Creek running from El Camino Real south to Fremont Avenue. County of Santa Clara owns park land along the creek south of Stevens Creek Boulevard. Complete creekside trail continuity has been precluded by subdivision development between Fremont Avenue and Stevens Creek Boulevard.

50. SARATOGA CREEK PARK CHAIN. Proposed. The many native sycamores along the creek make it one of our most attractive. Trails should be provided where not precluded by subdivision development. There is considerable publicly owned land between the creek and Lawrence Expressway suitable for a linear park.

51. LOS GATOS CREEK PARK. Partly existing. Connects by trail with Lexington Reservoir County Park, Vasona Lake County Park, and 80 acres of percolation ponds, and is being extended northwards to the confluence with Guadalupe River in downtown San Jose. The trail system is a joint project of the County, the City of Campbell, the Town of Los Gatos and the Santa Clara Valley Water District.

52. GUADALUPE RIVER PARK CHAIN. Proposed. Continuous trails for hiking and bicycling should be provided. Key features along the chain: Percolation ponds in the upper Almaden Valley; Park of the Guadalupe in downtown San Jose; City of San Jose-County Civic Center area; Santa Clara Valley Floor Park; the historic Lick Mansion, Brick Round House and Water Gardens now threatened by development.

53. COYOTE CREEK PARK CHAIN. Partly existing; additions proposed. Proposed to have continuous trails from Anderson Reservoir to San Francisco Bay, with trail connection to Coe State Park. Would link various existing parks, including the County's Hellyer Park and San Jose's Kelley, William Street, and Watson Parks. Currently has a seven-mile paved bicycle path and equestrian trail extending southward from Hellyer Park. A joint project of the City of San Jose, County of Santa Clara, State of California, and the Santa Clara Valley Water District.

54. PENITENCIA CREEK PARK CHAIN. Partly existing; additions proposed. Would make use of percolation ponds owned by Santa Clara Valley Water District. A joint project with the City of San Jose, Santa Clara Valley Water District, school districts, and Santa Clara County.

55. LOS ALAMITOS - CALERO PARK CHAIN. Partly existing. Being developed jointly by the City of San Jose and the Santa Clara Valley Water District. Flood control acquisitions on the basis of the limited flood plain concept are in progress. In some stretches the City of San Jose has worked with developers to acquire trail easements along the creek.

56. LLAGAS CREEK PARK CHAIN. Proposed. This stream's park chain potential will become more important as the South County grows. Flood control projects or urban development along the creek should be required to leave the creek in a natural state and provide for trails. Features of the park chain would include: an attractive little intermountain valley in the upper reaches of the creek along Casa Loma Road and Uvas Road and Chesbro Reservoir.

57. UVAS CREEK PARK CHAIN. Proposed. This beautiful South County stream should be protected as a park chain in advance of urbanization. Features of the chain include Uvas Reservoir and Gilroy's 29-acre Christmas Hill Park.

58. LITTLE ARTHUR CREEK PARK. Partially existing; undeveloped. One of the County's most beautiful intermountain valleys. Its gentle, streamside terrain complements nearby Mt. Madonna Park, where rugged terrain limits development potential; 17 acres.

59. PAJARO RIVER PARK CHAIN. Proposed. Any development proposals along the Pajaro should provide for maintenance of the natural quality of the stream and for trailways.

60. PACHECO CREEK PARK CHAIN. Proposed. Sycamore lined stream running through a narrow valley ringed with mountains. Picnicking and camping facilities along the creek would have great attraction for travelers using the parallel Pacheco Pass Highway (Route 152). Improvement of this highway should be carefully planned to preserve the natural beauty of the area and complement its recreation potential.

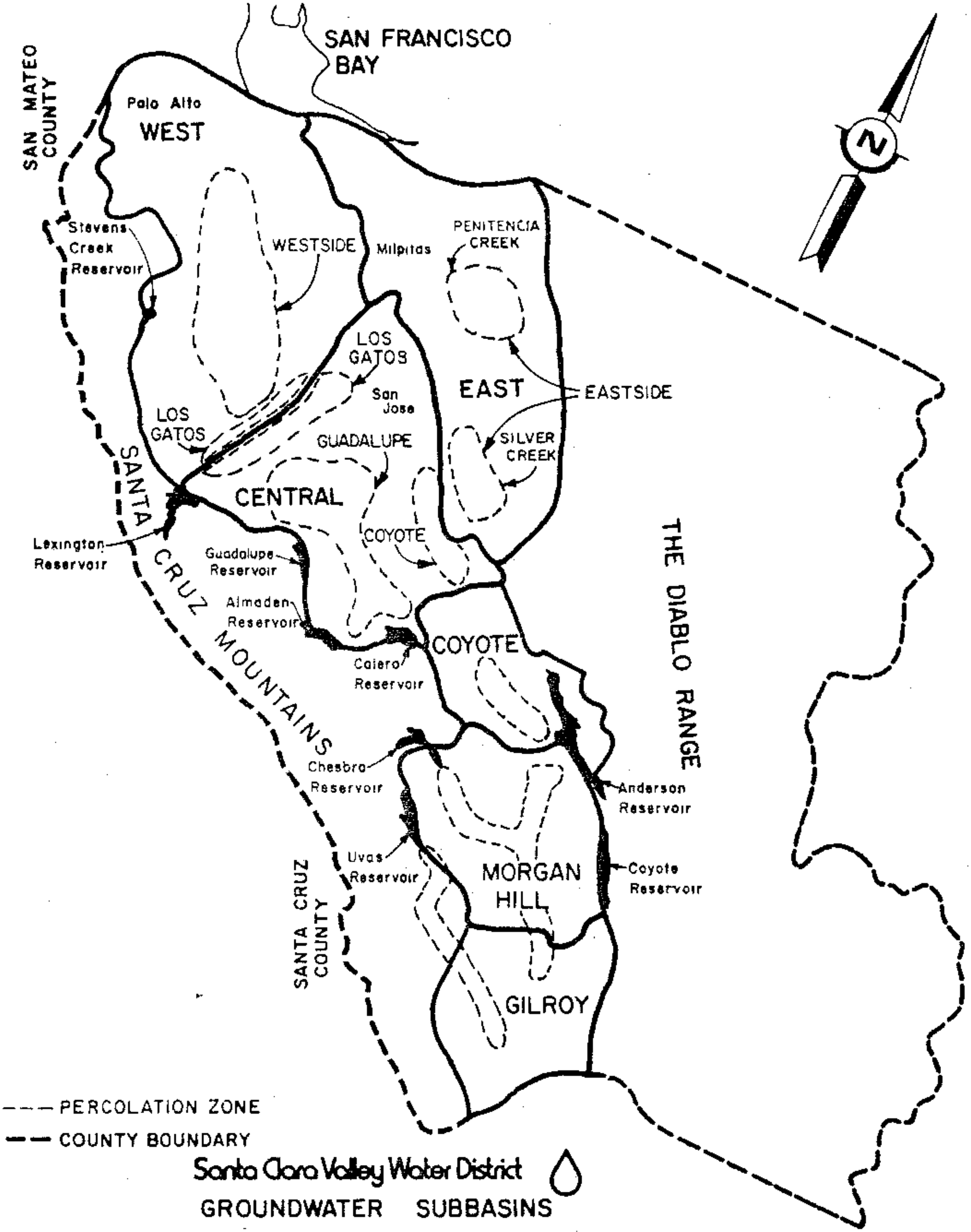
Groundwater Recharge

Groundwater systems consist of a groundwater basin and the associated in-stream and off-stream recharge facilities. In Santa Clara County, there are several interconnected groundwater subbasins, as shown in Figure 15. These subbasins presently yield over 65 percent of the annual water needs of the County.

Protection of the basins from prolonged overdraft has been a major concern in Santa Clara County since the early 1900s. Prolonged overdraft leads to subsidence, which not only permanently reduces groundwater basin storage capacity but can result in saltwater intrusion, damaged and dry wells, increased stream erosion and sedimentation problems, costly improvement or installation of flood control facilities in subsided areas (e.g. Bayfront levees), and costly structural repairs in subsided areas. The District supplements the naturally occurring groundwater by recharging imported water and water conserved in District reservoirs. Since average annual water use continues to increase in the County, overdraft and its associated problems continue to be a constant threat.

As the valley continues to develop, less and less land is exposed to the natural recharge process. This means that the District must protect existing on-stream recharge facilities and continue to develop off-stream facilities. Currently, the District maintains and operates over 300 acres of off-stream recharge facilities and releases water at controlled rates from reservoirs into every major stream channel in North Santa Clara County. Generally, the best recharge rates are achieved where the permeable, water-bearing sand and gravel layers of the valley's alluvial deposits are not sealed from the surface by impervious layers of clay. Therefore, the best areas for recharge are located closest to the foothills where the major streams enter into the valley floor. Table 13 lists the principal in-stream and off-stream recharge facilities in the County along with assumed recharge capacities.

The need to protect groundwater recharge areas may make certain project alternatives, such as concrete channel lining, infeasible or may require costly off-site mitigation. Furthermore, a groundwater recharge area indicates that the channel environment will be enhanced by a reliable source of water. Because the quantity of vegetation and quality of habitat are probably higher than average in groundwater recharge areas, there may be impacts on the maintenance program for that reach. For these reasons, the groundwater recharge status of a reach of stream is included in the environmental INVENTORY.



Santa Clara Valley Water District

GROUNDWATER SUBBASINS
IN SANTA CLARA COUNTY
DECEMBER 1975

Figure 15

TABLE 13

EXISTING RECHARGE RATES OF DISTRICT GROUNDWATER RECHARGE FACILITIES

RECHARGE SYSTEM	RECHARGE FACILITY	EXISTING1/ RECHARGE RATE AF/YR	AVERAGE SUMMER RATE AF/DAY	AVERAGE WINTER RATE AF/DAY
Stevens Creek	McClellan Pond	360	1	1
	Stevens Creek	3,650	10	10
	Subtotal	4,010		
Westside	Calabazas Crk.	2,920	8	8
	Regnart Crk.	730	2	2
	Rodeo Crk.	1,092	4	2
	San Tomas Crk.	1,460	6	2
	Saratoga Crk.	6,935	24	14
	Wildcat Crk.	Included in San Tomas Creek		
	Subtotal	13,137		
Los Gatos	Budd Avenue Ponds	8,040	24	24
	Camden Ponds	6,700	20	20
	Los Gatos Crk.	9,338	35	20
	McGlincey Ponds	6,700	20	20
	Oka Ponds	3,000	10	8
	Page Ponds	6,700	20	20
	Sunnyoaks Ponds	1,650		
	Subtotal	42,128		
Guadalupe	Alamitos Crk.	2,730	10	5
	Alamitos Ponds	3,390	13	8
	Calero Crk.	Included in Alamitos Creek		
	Guadalupe Ponds	3,780	21	0
	Guadalupe River	2,548	9	5
	Kooser Ponds	2,310	7	7
	Los Capitancillos Ponds	9,150	30	30
	Ross Creek	2,920		
	Subtotal	26,828		
Coyote	Coyote Cr. (Lower)	1,460	4	4
	Coyote Cr. (Upper)	12,775 2/	35	35
	Coyote Pond	11,280	56	8
	Ford Rd. Ponds	7,800	30	16
	Madrone Channel	4,860	16	12
	Main Ave. Ponds	3,500	10	10
	Silver Creek	730	3	1
	Thompson Crk.	730	3	1
	Subtotal	43,135		
Penitencia	Overfelt Gardens	1,092	4	2
	Penitencia Crk.	1,820	6	4
	Penitencia Ponds	3,650	10	10
	Subtotal	6,562		
TOTAL	NORTH COUNTY	135,800 AF/YR		
South County	Llagas Creek	12,045 3/	33	33
	Uvas Creek	9,855 3/	27	27
	Subtotal	21,900		
TOTAL	(ALL BASINS)	157,700 AF/YR		

1/ Unlimited "clean" water supply with present operations and maintenance.
2/ Recharge rate depends on rate of extraction in the Coyote Basin.
3/ Based on estimates with no data available.

CHAPTER 6
MAINTENANCE

This chapter discusses the effect of maintenance practices on the hydraulic efficiency of channels and on the magnitude of potential flood damages. These effects are determined using a computer program developed as part of the Waterways Planning Study. The input requirements for the program and output available from it are described in detail in the Users Manual.

For the purposes of the Waterways Planning Study, "maintenance" is defined as the program of routinely removing debris, sediment and vegetation from channels. Maintenance of channels actually includes much more than this, such as erosion repair work, rodent and weed control and fence repair. However, a major consideration in choosing the standard to which a stream channel should be maintained is hydraulic efficiency, or the ability of a channel to convey water given a certain level of sediment deposition and vegetative growth. A channel is defined as hydraulically "adequate" if it can convey the 100-year flowrate with no freeboard. An "inadequate" channel is one from which flooding is expected to occur in the 100-year event. This chapter of the Waterways Planning Study is primarily concerned with how maintenance practices affect the hydraulic adequacy of channels.

The District's Maintenance Division is currently in the process of implementing a Planned Maintenance Program modeled after the successful system developed by the Los Angeles County Flood Control District. This program operates by defining an acceptable standard of maintenance for each reach of each creek. When physical, visual or operational conditions of the channel fall below this standard, then predefined maintenance tasks are carried out which restore the channel to an acceptable state. The maintenance element of the Waterways Planning Study is intended to provide hydraulic and flood damage information which can be useful in defining the acceptable maintenance standard for each reach of creek. It is intended to supplement practical knowledge gained from stream maintenance experience, legal requirements, political considerations and other factors which determine what the acceptable maintenance standard should be and how maintenance work should be prioritized. Hydraulic and flood damage information in the maintenance INVENTORY will allow identification of reaches where maintenance activity could produce flood damage reduction benefits, i.e., would reduce or prevent damages and change the level of protection (frequency of flooding). It will also allow identification of reaches which have sufficient hydraulic capacity such that frequent maintenance is not required, thus freeing funds for other work.

Methodology

Hydraulic efficiency, or the ability of a channel to convey flow, depends on the cross-sectional area, invert slope and channel roughness. The cross sectional area can be reduced over time by sediment deposition, by vegetative growth, and by levee settlement. In some cases sediment may be the substrate upon which vegetation grows. Sediment and vegetation removal are tasks typically performed by the Maintenance Division.

Manning's roughness coefficient, or "n" value, used in hydraulic analyses is a somewhat subjectively chosen quantity. The hydraulic roughness coefficient is largely dependent on the amount and character of vegetation in the channel. As vegetation grows in a channel, limbs, stems and foliage induce turbulence and increasingly retard flow. As depth and velocity increase, the force of the flowing water tends to bend the vegetation. Therefore, the ability of vegetation to cause turbulence is partly related to its resistance to bending force. The amount and character of foliage varies with the time of year, i.e., whether it is the growing season or dormant season. In judging the retarding effect of vegetation, critical consideration should be given to the following: the height of vegetation in relation to depth of flow; the capacity to resist bending; the degree to which the cross section is occupied or blocked out; the transverse and longitudinal distribution of vegetation of different types; densities and heights in the reach under consideration. Table 14 is an example of how this parameter could be applied more consistently in hydraulic analyses and how it might be correlated more objectively with maintenance standards.

Minimum "n" values can be assigned according to channel type as shown in Table 15.

For each reach of creek, channel capacity, remaining freeboard and frequency of maintenance are calculated for a range of "n" values and for sediment levels of 0, 1 and 2 feet. The minimum "n" value, corresponding to the condition in a newly cleaned channel, is assigned according to channel type as shown in Table 15; the "n" value is then increased by .005 until a maximum value of .07 is reached. If, for a given roughness coefficient and sediment depth, the channel still has enough capacity to carry the existing one percent flowrate, remaining freeboard and estimated frequency of maintenance are calculated.

Frequency of maintenance is estimated assuming that, from a given beginning state, the channel's roughness coefficient increases by 20 percent each year and sediment level increases by an amount equal to the average annual sediment deposition, as calculated in the sediment element of INVENTORY. That channel roughness increases by 20 percent each year is an initial "best guess" which can be refined as more data about how creek conditions change over time are analyzed. Obviously, this assumption is not true for all creek reaches; for example, channel roughness may increase by less than 20 percent annually in a lined creek reach, and by more than 20 percent annually in a natural creek reach. Nor is it true that the percent increase will be constant each year; vegetative growth will be less in dry years and more abundant in wet years. However, over time this kind of variation will approach an average annual growth rate, just as sediment deposition will approach an average annual sediment deposition rate. The

TABLE 14

RELATION OF VEGETATIVE GROWTH TO MANNING'S "n" VALUES

Vegetation and flow conditions comparable to:	Degree of effect on "n"	Range in "n" value
Dense growth of flexible turf grasses or weeds, of which Bermuda and blue grasses are examples, where the average height is less than four feet.	Low	0.025 to 0.030
Supple seedling tree switches such as willow or cottonwood where the average height is less than three feet.		
Turf grasses where the average height is less than eight feet.		
Stemmy grasses, weeds or tree seedlings with moderate cover where the average height is less than four feet.	Medium	0.030 to 0.045
Brushy growth, moderately dense, similar to willows one to two years old, dormant season, along side slopes of channel with no signficant vegetation in excavated floodplain area.		
Turf grasses where the average height is about ten feet.		
Dormant season, willow or cottonwood trees eight to ten years old, intergrown with some weeds and brush, none of the vegetation in foliage.	High	0.045 to 0.070
Growing season, bushy willows about one year old intergrown with some weeds in full foliage along side slopes, no signficant vegetation in excavated floodplain area.		
Turf grasses where the average height exceeds the bank elevation.		
Growing season, bushy willows about one year old, intergrown with weeds in full foliage along side slopes; dense growth of cattails in excavated floodplain area.	Very High	0.070 to 0.120
Growing season, trees intergrown with weeds and brush, all in full foliage.		

TABLE 15

MINIMUM "n" VALUES FOR VARIOUS CHANNEL TYPES

Channel Type	Minimum "n" Value
Pipe	0.013
Box Culvert	0.013
U-frame concrete	0.013
Trapezoidal concrete	0.013
Sacked concrete riprap	0.025
Gabions - sides and bottom	0.030
Earth levees	0.030
Floodwalls	0.030
Excavated earth	0.030
Widened earth - one side	0.030
Excavated earth bypass	0.030
Modified floodplain	0.030
Natural - unmodified	0.030
Gabions - sides only	0.035
Rocklined - sides only	0.035
Rocklined - sides and bottom	0.035

frequency of maintenance is the amount of time which can elapse before the channel will deteriorate such that freeboard is decreased to a specified minimum. Thus, it is the maximum interval between maintenance activity on the creek, the time which elapses between some beginning adequate condition and some specified inadequate condition. For example, a channel that has a beginning "n" value of .035 and no sediment deposition might have a capacity to carry the one percent flowrate with three feet of freeboard. The frequency of maintenance would be the estimated time which can elapse before sediment deposition and vegetative growth reduce channel freeboard to the specified minimum e.g., 2 feet.

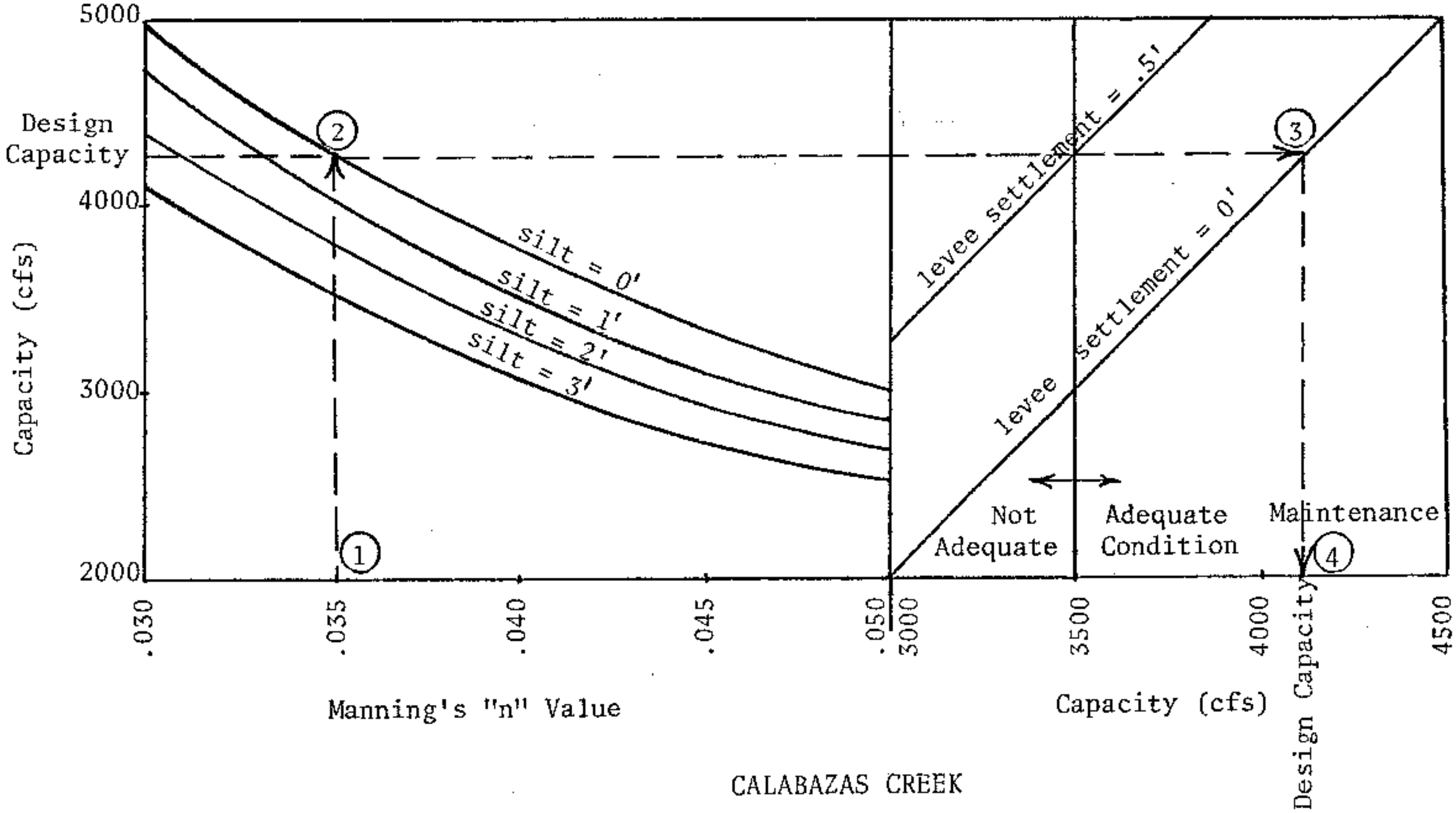
The maintenance element of INVENTORY also investigates benefits associated with intensive maintenance (minimum "n" value and no sediment deposition). These benefits are the reductions in average annual flood damages associated with intensive maintenance conditions, i.e., maximum possible channel capacity and minimum frequency of flooding. By analyzing benefits obtainable through minimum-interval (i.e., intensive) maintenance and comparing with benefits obtainable through maximum-interval maintenance, a judgment can be made regarding optimization of available maintenance program resources.

The maintenance element of INVENTORY also includes information on the environmental quality classification of each reach of creek relative to existing "n" value, average annual sediment yield, channel capacity and frequency of flooding.

Using the information developed in the maintenance element of INVENTORY, parameters which affect the hydraulic efficiency of a reach of channel, such as Manning's "n" value, sediment depth, and amount of levee settlement (if this applies), can be illustrated in a graph such as that shown in Figure 16. Figure 16 shows how maintenance parameters and channel capacity are related for Calabazas Creek in the reach between Guadalupe Slough and Bayshore Freeway. To use the graph, enter with an existing value of Manning's "n" 1 , go up to the appropriate level of siltation 2 ; then move right to the appropriate levee settlement line 3 and drop to the capacity axis 4 . The example shows that for design conditions of Manning's "n" equal to 0.035, no siltation and no levee settlement, the design capacity is about 4,200 cfs. If there were no levees in the example reach, then the graph could be simplified by omitting the levee portion of the graph and moving directly from point 2 to the left to the capacity axis. Similarly, the channel capacity for various combinations of conditions are readily obtainable for use in maintenance program decision-making.

FIGURE 16

EXAMPLE OF GRAPH RELATING MAINTENANCE PARAMETERS TO CHANNEL CAPACITY



CALABAZAS CREEK

Guadalupe Slough - Bayshore Freeway

Design Conditions:
   Manning's "n" = .035
   Siltation = 0 ft.
   Levee settlement = 0 ft.

CHAPTER 7
THE ELEMENTS OF A FLOOD DAMAGE REDUCTION AND STREAM MANAGEMENT PROGRAM

The Flood Damage Reduction and Stream Management Program is a family of problem solutions called "ELEMENTS". A complete list of the ELEMENTS are shown in Figure 17. These ELEMENTS can be separated into four groups:

Flood Damage Reduction

Erosion/Sedimentation

Environmental Quality

Maintenance

The purpose of this chapter is to describe and to discuss the advantages and disadvantages of these ELEMENTS in detail.

A computer program has been written which evaluates the feasibility of each ELEMENT for solving flood damage or other stream management problems such as erosion. The program then identifies possible FUNDING sources which may be used to finance each feasible ELEMENT. For example, the program may identify that channel modifications will solve a flooding problem and that the project is likely to meet the qualifications of a Corps' Small Flood Control Project. The computer program which screens possible solutions or ELEMENTS and FUNDING sources for all creek reaches is called the Decision Matrix program. The purpose of this section is to describe the process used in this program to make a preliminary assessment of an ELEMENT'S cost and applicability, and to identify those ELEMENTS which are evaluated in other parts of the Waterways Planning Study. For example, ELEMENTS of the Maintenance Program are discussed in greater detail in the Maintenance chapter.

Flood Damage Reduction

This section contains the ELEMENTS used to reduce or prevent damages caused when water escapes from the channel. These ELEMENTS may be structural or non–

structural and may range from floodwalls and levees which confine flow, to flood insurance which enables those flooded to recover from the effects of the flooding to some degree.

The Flood Damage Reduction Program consists of four functions:

Protection of Existing Development

Removal or Conversion of Existing Development

Discouragement of Development in the Floodplain

Regulation of Uses in the Floodplain

Each of these four functions contain ELEMENTS which are listed in Figure 17.

Protection of Existing Development

Flood Control Works

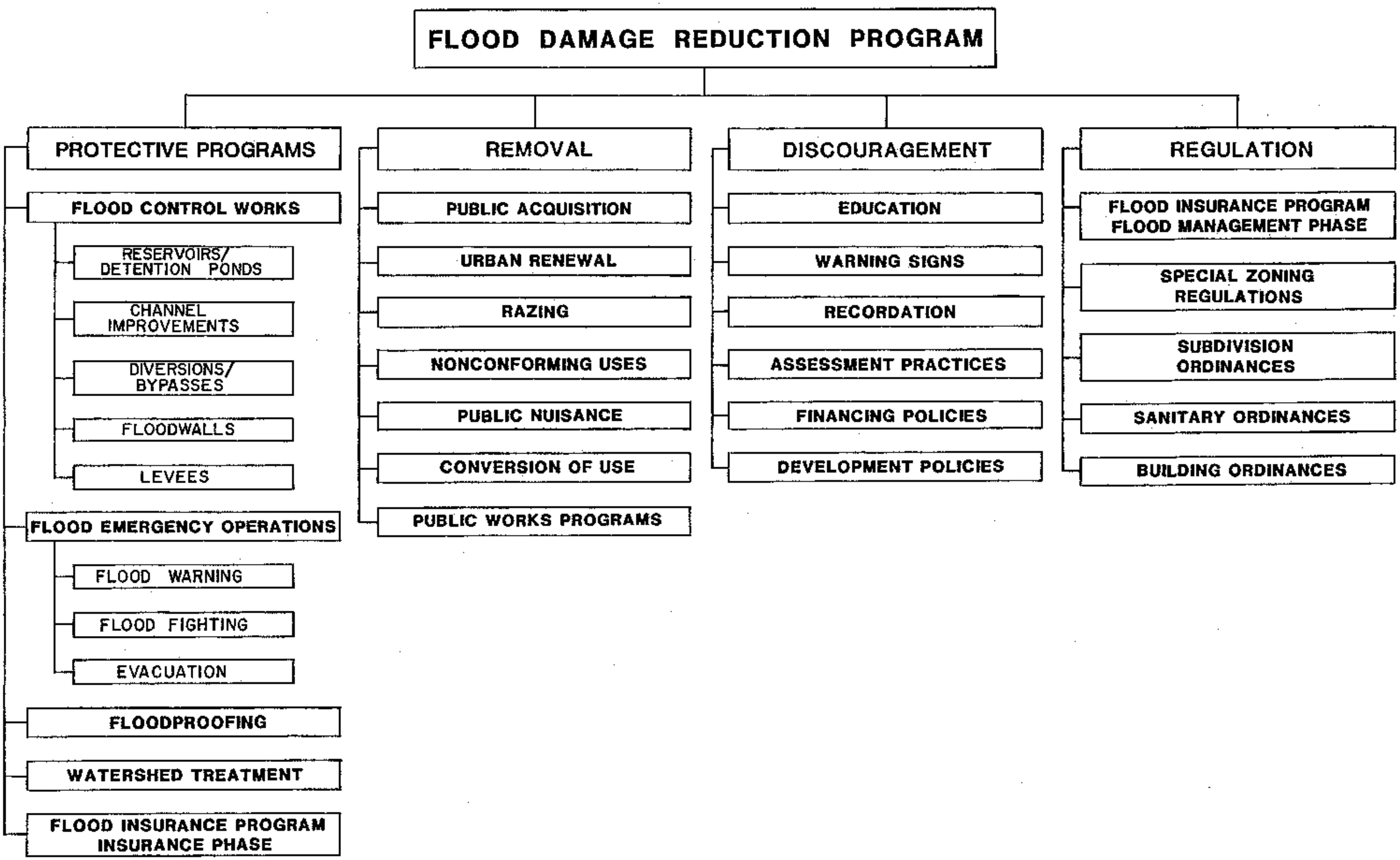
Flood control works are physical structures that are used to reduce, retard, or prevent the flow of storm waters, mud, and other debris onto natural flood plains and to convey storm and flood waters past areas to be protected. The principal types of structural facilities, which are often combined in a flood protection project, are reservoirs, detention ponds, diversions, bypassess, channel modifications, levees and floodwalls. Structural features are designed to provide protection against a specific design flood. Sometimes they can be incorporated at a relatively low cost as part of a multipurpose project, e.g., flood storage reservations in a major multipurpose reservoir.

Reservoirs - A reservoir is a stream impoundment with controlled outlets. They can be designed either primarily to reduce flood problems downstream or to serve purposes other than flood control such as water supply, hydro-power generation and recreation.

When a large storm occurs upstream of the reservoir, the storm waters are captured in the flood storage space, and, at the same time, releases from the reservoir are increased to move the storm waters downstream without exceeding the downstream channel capacity. If the storm and resulting volume of water are at or below the design

Figure 17

ELEMENTS OF A FLOOD DAMAGE REDUCTION PROGRAM



SOURCE: Adapted from materials published by the Southeast Wisconsin Regional Planning Commission, the Tennessee Valley Authority and the U.S. Army Corps of Engineers.

flood, operation of the reservoir in this manner will result in maintaining downstream flows at or below channel capacity.

The delay of the flood crest provided by the flood storage reservoir also allows the reduced flood crest to pass through the downstream system after local peak inflow to the downstream channel has passed. Discharge of storm water from the reservoir may then be accomplished by releases which do not exceed the downstream channel capacity.

The most important requirements that must be satisfied for a reservoir to be feasible include:

1. A site must be available that is large enough to provide storage necessary to reduce downstream flows.

2. The proposed dam site must be geologically suitable.

The benefits of reservoirs are that they provide significant protection for a long reach of the river downstream of the dam. This protection often eliminates the need for channel modifications that are economically and environmentally more costly. Reservoirs also can have recreation, water supply, hydropower and other benefits.

A disadvantage is the difficulty in finding sites for a reservoir that is both large enough and geologically suitable. Reservoirs are expensive and time consuming to build. Reservoirs can cause significant public controversy from people who have environmental concerns, landowners whose property will be inundated, taxpayers who must pay for the construction of the dam and others. Addressing these concerns can be very time consuming and delay start of the project.

The procedure for making a preliminary determination of the effect and feasibility of a reservoir for flood control purposes is outline below.

1. Determine first if there is a site available which is large enough and is geologically suitable, either by researching previous reports (Summary of Dam and Reservoir Investigations in Santa Clara County) or by requesting preliminary geological investigation. Also evaluate any existing reservoirs to determine if they can be enlarged.

2. Estimate storage capacity requirements for reservoir by two routing trials.

   a. Assuming the entire hydrograph is stored in the reservoir, determine the storage volume required (AF) and the flow rate at all existing flood points downstream.

   b. Assuming the reservoir peak outflow is limited to one-half the existing peak (or any more appropriate value), determine the storage volume required and the reduction in flow rate at all existing flood points downstream.

   c. Summarize data in following table.

Reservoir Storage Alternative - Site A (Sta #)

Reservoir Capacity	Reservoir Outflow	1% Flowrates at Downstream Pts. Sta. #1	Sta. #2	Sta. #3	Sta. #4
Existing	Q				
AF/2	Q/2				
AF	0				

   d. Benefits are derived from the reduction in average annual damages due to the reduction in flow from the reservoir.

3. Experience with the existing dams in the County indicates that the fill required for rolled earth dam construction can be estimated using the following equation:

Fill (Cubic Yards) = 100 x Storage Capacity (Acre-Feet) (Eq. 7-1)

In the absence of other data this value is acceptable.

4. The cost of dam construction including spillway and other associated structures can be estimated as $20 per cubic yard of fill (1982 dollars). This unit cost includes contingencies, engineering and inspection. Using Equation this gives a cost of $2,000 per acre-foot of storage. There will also be substantial costs for purchase of land for the dam and the area to be inundated and for relocation of roads, utilities and other facilities.

5. The time it takes from inception to completion of a reservoir usually requires more than five or seven years.

Because of the potential benefits, use of reservoirs should be examined whenever possible. Since existing reservoirs are located at suitable sites already, they should be examined for possible enlargement.

Detention Ponds - Detention ponds typically are small impoundments with uncontrolled outlets. They may be created by building a dam, by embankments, by excavation, or by a combination of these. Usually they are designed to detain the water in the pond to achieve a reduction in the peak flood stage downstream. They may be designed for use as a park site or for recreation purposes.

Detention ponds operate similarly to reservoirs but have less capacity. On-stream detention ponds store initial flows and perhaps delay the time when the peak flow moves downstream. Off-stream detention ponds can be designed to reduce the magnitude of peak flows by peak "scalping" such as was done with Lake Cunningham.

Since volume of detention ponds is usually small compared to the total volume of flow during a one percent event, the overall effect of a pond is limited. Ponds are most effective when located close to a problem area. Detention ponds should not be relied upon to provide an appreciable flood control improvement at areas of major flood damage on large rivers.

The advantages of detention ponds are that they can minimize or eliminate a local flooding problem sometimes at relatively low cost and they can be used for recreation.

A disadvantage of detention ponds is that they do not solve large problems. Also, ponds are designed to eliminate flooding for a specific flood hydrograph; if a storm has a different shape or magnitude hydrograph the pond may be ineffective. Finally, detention ponds often may not be feasible in highly developed areas where the cost to acquire the land may be very high.

Use of detention ponds is limited to on-site development mitigation of increased flows. Since they cannot solve large magnitude flood problems, individual detention ponds will not be identified as a flood problem solution in the Waterways Planning Study.

Channel Modifications to Increase Capacity - Stream channels may be modified to enhance the capacity of the stream channel to carry greater flows, thereby reducing the height, extent, or duration of overflow to the floodplain. Channel modifications include deepening, widening, straightening or lining the stream channel, removing obstructions and enlarging or replacing bridges and culverts. Channel modifications are a direct way to deal with specific localized flood problems, such as those in congested developed areas. They also may be useful or necessary in combination with other structural measures for flood control. A channel often is lined to protect its banks and/or bed from erosion. Lining materials include concrete, gabions, sacked concrete and rock rip-rap.

Channel modification will eliminate flooding and damages for flows up to and including the design flow (usually the 100-year flow). Channel modifications also have the advantage that the solution to flooding from an inadequate reach is solved at the location of the problem and with a minimum of right of way. The solution can be one which makes future maintenance easier and less costly.

Channel modification projects are costly because they can include land acquisition, substantial earth moving, channel lining and culvert enlargement. The modifications can cause severe damage to or even eliminate the riparian ecology.

Channel modifications are feasible in an urban area where the damages prevented are of the same order of magnitude as costs of the modifications and where there is little or no significant stream environment. In the preliminary screening for 'ELEMENTS" in the Waterways Planning Study, channel modifications were assumed to be feasible in every case. Therefore they are identified as a possibility for every creek or reach. When channel modifications increase flooding in downstream reaches, the modification of the upstream reach would have to wait until the inadequate downstream reach is completed.

Diversion - A diversion prevents flood damages in a watershed by conveying some flood flows from one watershed to another. A diversion would be used if channel modification is not feasible for reasons such as environmental sensitivity of an area or cost of acquiring right of way. Generally, a diversion project has an overflow structure in the watershed being protected that diverts all or some of the flow above a certain amount to the recipient watershed. The water can be transferred in either a pipe or an open channel.

The purpose of a diversion is to eliminate flood damages not to shift the location where the damages occur. Therefore, an analysis will be required to determine if the increased flow in the stream receiving the diverted water will cause or increase flooding on the recipient stream.

Diversions can result in legal problems for the District. If flooding occurs on the recipient stream when water was being diverted into it, then some of the flooding could be attributed to the effects of the diversion and the District, which would be responsible for the diversion, may be held liable for a portion of the flood damages. There also may be legal questions concerning water rights associated with interbasin transfers of water.

A comparison of the advantages and disadvantages show that a diversion can result in many problems and is usually not the best solution. Therefore, diversions will not be evaluated as potential flood damage reduction facilities.

Bypass - A bypass is an auxiliary channel used to pass floodwaters around an area where channel improvements are not feasible. Eventually the bypass returns the water to the stream from which it came. Bypass systems are used in flood damage reduction projects when the potential flow is much larger than the capacity of the existing river channel.

Bypass systems are needed only during major floods, and lands reserved for this purpose can be used for agriculture, wildlife management, recreation, or other compatible uses at other times. Bypass lands may be owned by the public and leased back to private users, or a flowage easement may be obtained for the project with the lands in private ownership.

A bypass can preserve large amounts of open space in agriculture or as a park. It may allow the preservation of the stream environment. However, a bypass may require the purchase of substantial amounts of land which is very costly or implementation of land use controls which require constant political vigilance to maintain.

Because of high land cost, especially in urban areas, this alternative may be feasible only in a few cases where it is undesirable or technically infeasible to modify the main channel. Where channel modifications are identified in the Waterways Planning Study, a bypass alternative will be analyzed where the existing stream system has a significant environmental habitat, and the right-of-way is not restricted by development.

Levees - Levees are earth embankments placed along the stream to contain flood waters and thereby protect surrounding lands from inundation. Levees may be placed close to the edge of a stream channel or may be set back away from the stream, thus enclosing a portion of the floodplain (modified floodplain). The side slopes of a levee may be quite steep, 2 to 1, or quite flat, up to 8 to 1. Steeper levee side slopes and those close to the channel where velocities are higher may require protection from erosion by placement of forms of bank protection such as rock, concrete or gabions.

Levees are simple and inexpensive to build. They can be made to blend in with the landscape of parks and open space and can be used as bike paths or trails. Also, since levees are located on the banks above streams, the impact of levees on the riparian ecosystem can be minimized.

One disadvantage of leevees is that failure of a levee is catastrophic and may result in more damages than if the project had never been built. Levees also require a wide right of way which may be costly in urban areas. In some settings a levee may have adverse visual impacts especially if landscaping is difficult.

In the preliminary screening for ELEMENTS in the Waterways Planning Study levees will be specified: 1) when channel modifications are necessary, 2) when the stream has significant environmental habitat and 3) when there is a possible recreational use.

Floodwalls - Floodwalls are used in areas where the right of way is too narrow to allow installation of standard levees. Floodwalls are built on top of existing creek banks and levees.

For general planning purposes it was assumed that floodwalls will be no higher than four feet including two feet of freeboard. When walls exceed four feet they begin to have an adverse visual and aesthetic impact on the surrounding community. Floodwalls will be identified as a possible ELEMENT where right-of-way is restricted or the stream environment is of significant quality and the confined water surface is less than 2 feet above the banks.

Flood Emergency Operations

A reliable and comprehensive flood emergency operation can help protect the safety and welfare of the community and reduce damage. A complete operations program for flood emergencies can include flood warning, flood fighting or temporary evacuation.

Warning and emergency operations systems should establish clearly:

- What kind of warning and recommendation for action will be communicated.
- Through what medium the warning will be communicated.
- Under what conditions a warning will be issued.

Measures for emergency operations and recovery efforts require equally careful consideration of who is to do what under what set of conditions. Participants should know what they are expected to do and should have the resources to do it. Such measures will involve not only the variety of government agencies at various levels but also private groups. To be effective warning and emergency measures must be designed so they can be put into effect on very short notice.

Recovery and rehabilitation measures taken after the immediate emergency are an important part of an emergency operations program.

Implementation of a flood emergency operation system will be the first ELEMENT identified for an urban area with potential flood damages.

Flood Warning - A flood warning system is designed specifically for detection of severe weather and the forecast of precipitation intensity. The best forecasts incorporate analyses of antecedent conditions such as soil moisture, correlated with weather forecasts of temperature and precipitation. Flood forecasting information broadcasted immediately to residents in floodprone areas can result in savings of life and property.

In those areas without flood protection or where the flood may exceed creek capacity, a well coordinated flood warning system that allows people to prepare their homes and/or leave the area before the flood occurs will save lives and limit property damage. However, in areas such as Santa Clara County the hydrologic characteristics of the streams cause flooding to occur very soon after peak rainfall occurs. For these rivers there is not enough time to analyze events, to determine where flooding will occur and then to alert residents of the area before the flooding occurs. Therefore, it is questionable whether flood warning is a tool with wide applicability in this County.

A flood warning system is only effective where the warning agency has sufficient time to determine where and when a flood will occur. Therefore, the time it takes for a flood flow to pass through each watershed should be identified. Then the lag time between peak rainfall and peak flooding should be determined. All areas with a lag time in excess of eight hours should have a flood warning system set up for them.

Flood Fighting - Properly coordinated flood fighting efforts can result in substantial reduction in flood damages and loss of life. A flood fighting program requires coordination with City, County and perhaps State personnel. A flood simulation model and data interrogation system would be very useful to identify critical points where flooding may occur given a particular pattern of rainfall and stream flows.

The usefulness of emergency measures can be enhanced by advance preparation of flood emergency manuals which identify responsibility and capability of organizations and specific individuals who can help in flood emergencies. Sandbags can be stockpiled and sources of material and equipment can be earmarked to help make best use of all resources during flood emergencies.

Evacuation - Temporary evacuation of floodprone areas during a flood emergency will reduce loss of life and damage to movable property. Precautionary or escape evacuations usually are accomplished under the leadership of local public safety and emergency service agencies with appropriate technical advice from the National Weather Service, the Corps of Engineers or local water district officials. A successful evacuation would require planning of how the evacuation would take place and public education about the plan before flooding becomes possible. The evacuation itself would require trained personnel, cooperation among agencies and adequate warning from a flood forecasting system.

Relief and Restoration - For those whose homes are damaged and who need assistance so that they can return to their homes, and those who take up alternative quarters while their homes are being restored or until new accommodations are located, various assistance programs are available to meet essential needs not covered by insurance. None of these programs will replace all losses. These relief and rehabilitation programs are generally the same for victims of all natural disasters, with only the National Flood Insurance Program applying uniquely to flood or mudslide disaster.

The current relief and rehabilitation programs were institutionalized and coordinated by the Disaster Relief Acts of 1970 and 1974. The latter placed the reorganized federal disaster response under the direction and coordination of the Federal Disaster Assistance Administration (FDAA) in HUD. The FDAA has been reorganized as a component of the Federal Emergency Management Agency. Federally funded flood relief programs are triggered by a Presidential Declaration of a Major Disaster upon request of the governor of an affected state.

Floodproofing

Existing structures that cannot be economically removed from or, which of necessity, must be erected on floodplains, such as certain public utilities and warehouses, should be floodproofed to prevent or reduce flood damage. Floodproofing allows land susceptible to occasional flooding to be used for some purpose. Floodproofing should only be considered where floods are expected to have low stage, low velocity, and short duration. Floodproofing measures include structural modifications and operational and management safeguards. The structural modifications and special installation methods are the most desirable as they would not depend upon any warning, judgment, decision or action to put them into effect.

Structural modifications include the reinforcing of basement walls and the underpinning of floors to withstand the hydrostatic pressures of floodwaters, permanent sealing of all exterior openings to basements with impervious materials, use of masonry construction, erection of low floodwalls and, where possible, the elevation of the lowest floor, flood-vulnerable utilities, and access roads at least two feet above the 100-year recurrence interval flood level.

Operational and management safeguards include special actions during floods or in anticipation of floods such as the removal of valuable items from flood-vulnerable areas or the elevation of such items above flood levees; the waterproofing, disconnection, elevation, or removal of all electrical equipment from flood-vulnerable areas; the avoidance of the use of flood-vulnerable areas such as basements for living, sleeping, or cooking functions; operation of emergency pump equipment; erection of sandbag levees; and the shoring of weak walls or other structural elements.

The advantages of floodproofing are that damages to structures and contents are reduced or prevented, architectural design and construction techniques are well-known, and the occupancy of a floodplain site and surrounding infrastructure is allowed under controlled conditions.

The disadvantages are that flooding of surrounding areas still occurs with possible damages to other facilities and services and emergency access can be difficult during flooding events.

One of the products of the Waterways Planning Study is an analysis of the cost of floodproofing all structures in the floodplain. This information allows comparison of the costs of floodproofing with the costs of other alternative methods of flood damage reduction. Floodproofing will be selected as an option where the costs are less than or equal to the cost of channel modifications.

For the purpose of this report, it was assumed that floodproofing was accomplished by construction of concrete masonry walls for each structure, or in some cases, for a group of structures. The cost of raising individual structures above flooding elevations was found to be very close to that of wall construction and was treated as essentially equal since the unit cost values used for development of each of the alternative's cost might vary plus or minus ten percent.

The floodproofing wall would be of concrete masonry and built directly against the outside wall of the home or apartment being protected. The wall height would provide protection from the one percent flood plus one-half foot of freeboard, and would be designed to resist floodwater loadings in excess of the existing structure's lateral loading resistance capacity. It would be constructed so that it encircled both the living quarters and the garage. The wall would consist of decorative block or would be painted to match or be compatible with the appearance of the existing structure. Temporary wooden or aluminum closures would be provided at the garage door and other openings.

The unit cost of a floodwall, in \$/linear foot, varied depending on the land use: floodproofing for residential structures, both high density and detached single family, was assumed to be \$50/foot. Floodproofing of other structures was assumed to cost \$100/foot. The length of the floodwall was found according to the following steps:

1. Determine the percent of the total land area that is occupied by the structure. Factors for this for various land uses are given in Table 16.

2. Determine the area of the building and assume this area is a square.

3. Find the length of one edge of the square by taking the square root of the area of the square.

4. The length of the floodwall is then four times the length of the edge of the square.

5. The cost of floodproofing then is the product of the length of the floodwall.

TABLE 16

FACTORS USED TO ESTIMATE COSTS OF FLOODPROOFING

Land Use	Unit Cost of Floodwall $/lin Foot	Percent Land Occupied by Structure
Single Family Residential	50	*
High Density Residential	50	80
Mobile Homes	100	100 **
Commercial/Industrial	100	50
Public Use	100	40

* Average house assumed to be 2100 square feet
** Assume wall around entire mobile home park

Examples of how these rates are used to calculate floodproofing cost are given in Figure 18.

FIGURE 18

EXAMPLES COMPUTATIONS OF THE COST OF FLOODPROOFING

Land Use: Residential

Given: 2 acres of residential land; high density apartments; assume structure covers 80% of the area; cost of floodwall is $50 per foot, from Table 3.

Area occupied by structure $= 2 \text{ acres} \times \frac{43560 \text{ ft}^2}{\text{acre}} \times .8$

$= 69{,}696 \text{ ft}^2$

Length of edge of square $= 69{,}696 \text{ ft}^2 = 264 \text{ ft/edge}$

Cost of Floodproofing $= 264 \text{ ft/edge} \times \$50/\text{ft} \times 4 \text{ edges} = \$52{,}800$

Land Use: Public Service

Given: School on 2 acres; assume structure covers 40% of the area; cost of floodwall is $100/foot, from Table 3.

Area occupied by structure $= 2 \text{ acres} \times \frac{43560 \text{ ft}^2}{\text{acre}} \times .4 =$

$= 34{,}848 \text{ ft}^2$

Length of edge of square $= 34{,}848 \text{ ft}^2 = 186.68 \text{ ft/edge}$

Cost of flood-proofing $= \$186.68 \text{ ft/edge} \times \$100/\text{ft} \times 4 \text{ edges}$

$= \$74{,}670$

Watershed Treatment

Proper management of the upper watersheds can result in greater water retention capability and reduced erosion and sedimentation problems. Protection of watershed land is achieved through the application of various systems of conservation practices. These include conservation cropping systems, crop residue use and minimum tillage on crop land, along with cover and green manure crops in orchards. Range land seeding and cross-fencing will achieve proper grazing use. Terracing and regrading can improve water retention. Watershed treatment also should include a fire control program with access roads and fuel breaks.

Watershed treatment can reduce flows downstream of the site of the treatment and reduce or minimize the size and cost of downstream damages or flood control works. In addition, most watershed treatment actions preserve the productivity of the soil by preventing erosion and loss of nutrients.

A disadvantage of watershed treatment is that the effect of land treatment on stream flow reduction is limited. Therefore, land treatment will only be evaluated as a potential flood damage reduction element, where average annual damages are low; the watershed is mostly rural, the flooding is very infrequent and there are associated sediment problems.

Flood Insurance Program - Insurance Phase

The U.S. Congress created the National Flood Insurance Program which has two goals: to mitigate the effect of floods on those owning structures already located in the floodplain and to control land use to prevent location of new structures where they would be damaged by floods. The first goal is discussed below; the land use controls are presented later.

Established in 1968 and broadened in 1969, 1973 and 1975, the damage mitigation portion of the program enables property owners to acquire flood insurance at subsidized rates through a cooperative program with the private insurance industry. Before property owners can obtain such flood insurance, the local community (city or county) must join the program. Joining in the Federal Program requires that those communities with designated flood hazard areas adopt and enforce floodplain management measures that require future development be protected from future floods. In communities that join the program, the availability of federally related funding for property (example: loans by banks or federally funded relief or disaster assistance) located in a designated flood hazard area is conditional upon the purchase of flood insurance.

The flood insurance program is conducted in two phases: an "Emergency Program" and a "Regular Program". Under the emergency program property owners can purchase flood insurance at rates subsidized by the federal government. The maximum amount of damages covered by this program and the rates paid to obtain that coverage as of February 1982 are presented for each land use in Table 17.

Under the Regular Program, the full limits of flood insurance coverage become available locally. The premiums charged for new construction vary according to the exposure to flood damage. The community's floodplain management efforts become more comprehensive: new buildings are elevated or flood proofed above certain levels. These levels are derived from HUD's detailed on-site engineering survey in the community. The detailed map is a Flood Insurance Rate Map which shows flood elevations and outlines risk zones used for insurance purposes. The extra amounts of damage for which protection can be obtained and the maximum cost of coverage (as of February 1982) are presented in Table 17. Table 17 also presents the total coverage available from both programs and the maximum that a lender can require a property owner to purchase.

The FIA has several other options besides just reimbursing property owners for damages sustained: acquisition of damaged property covered by flood insurance and relocating damaged structures out of the floodplain. Although these options are used infrequently the FIA may use them more often in the future to permanently reduce the number of structures endangered by floods.

TABLE 17

FLOOD INSURANCE RATES UNDER NATIONAL FLOOD INSURANCE PROGRAM
As of February 17, 1982

		"Emergency Program" Put In Place Before Any Data Developed To Assess Risks		"Regular Program" Instituted After Development of Enough Data To Assess Actuarial Risks		Total Sum of Emergency Regular Program	
Land Use	Type of Damage	Amount of Damages For Which Coverage Is Available	Government Subsidized Rate per $100 Of Coverage	Amount of Damages For Which Coverage Is Available	Maximum Rate per $100 Of Coverage Based on Actuarial Risk	Total Damage For Which Coverage Is Available	Maximum Coverage That A Lender Can Require
Single Family Residential	Structure	$35,000	$.40	$150,000	$.50	$185,000	$70,000
	Contents	10,000	.50	50,000	.75	60,000	20,000
High Density Residential	Structure	100,000	.50	150,000	.50	250,000	200,000
	Contents	10,000	1.00	50,000	.75	60,000	20,000
Mobile Homes	Structure	35,000	.50	150,000	.50	185,000	70,000
	Contents	10,000	1.00	50,000	.75	60,000	20,000
Commercial	Structure	100,000	.50	150,000	.50	250,000	200,000
	Contents	100,000	1.00	200,000	1.10	300,000	200,000
Industrial	Structure	100,000	.50	100,000	.50	200,000	200,000
	Contents	100,000	1.00	100,000	1.10	200,000	200,000
Public Service	Structure	100,000	.50	100,000	.50	200,000	200,000
	Contents	100,000	1.00	100,000	1.10	200,000	200,000

FIA now has a mechanism which may allow some individuals to accomplish permanent relocation out of the floodplain. This mechanism, referred to as a Constructive Total Loss (CTL) declaration, can be authorized solely by the Federal Insurance Administrator. For consideration prior to final approval, those structures eligible for this declaration must have been damaged while a Standard Flood Insurance Policy was in force and, as a result of the nature of those damages, are precluded from repair or reconstruction because of the denial of the local community to approve a building permit application. This CTL final settlement under the flood insurance policy may allow an insured homeowner to be paid up to the full face value of the policy in force at the time of the subject loss.

Figure 19 gives examples of how the costs of providing flood insurance is determined under the Emergency and Regular Programs.

Where it is too costly or difficult to provide structural flood protection, the existence of the flood insurance program is a benefit because the property owners are protected from catastrophic economic losses. Also, the requirement to buy insurance alerts the potential purchaser of a property owner to assume some of the burden of providing the protection he receives. Flood insurance also is useful as an interim measure while waiting for physical flood protection measures to be constructed.

The purchase of flood insurance by the District on behalf of the property owners, or the reimbursement by the District to the property owners, was eliminated from consideration because such an action might be construed as an admission of liability. There is also a question of whether or not such a payment might be considered a gift.

There are significant costs associated with a flood emergency which are not covered by the mandatory flood insurance including: costs of flood emergency operations, indirect flood damages such as business loss, damage to structure contents, damge to public facilities such as roads and bridges, and damage to accounts, bills, valuable papers or records, fences, retaining walls, swimming pools landscaping, crops and livestock.

FIGURE 19

Example Computations of Flood Insurance Rates

I

Given: Land Use - Residential Single Family
Land Area - 5 acres
Density - 5 dwelling units/acre
Structure Value - $80,000
Contents Value - $24,000 = 30% x structure value

Rates used (from Table 17 as of February 1982)
Structure
$0.40/$100 for first $35,000 Emergency Program
$0.50/$100 for value above $35,000 and less than $185,000 Regular Program
Contents
$0.50/$100 for first $10,000 Emergency Program
$0.75/$100 for next $50,000 Regular Program

Computation:

Structure					
$35,000	x	$.40/$100	=	$140	
($80,000 - $35,000)	x	$.50/$100	=	$225	
Contents					
$10,000	x	$.50/$100	=	$50	
($24,000 - $10,000)	x	$.75/$100	=	$105	
Total annual for structure and contents				$520	/year

II

Given: Land Use - Industrial
Land Area - 10 acres
Density - 1 structure/acre
Structure Value - $94,600
Contents Value - $236,500 = 250% x structure value

Rates Used (from Table 17 as of February 1982)
Structure
$0.50/$100 for first $100,000 (Emergency Program)
$0.50/$100 for next $100,000 (Regular Program)
Contents
$1.00/$100 for first $100,000 (Emergency Program)
$1.10/$100 for next $100,000 (Regular Program)

Computation:

Structure					
$94,600	x	$.50/$100	=	$473	
0	x	$.50/$100	=	0	
Contents					
$100,000	x	$1.00/$100	=	$1,000	
$100,000	x	$1.10/$100	=	$1,100	
$36,500	x	0	=	0	
Total Annual Cost				$2,573	/year

Flood insurance is an option which will be identified wherever there are flood damages in an urban area. At the very least it will provide interim protection until a project can be built. The cost of insurance and the level of protection will be weighed against other alternatives to determine the feasibility of flood insurance as a long term solution.

Removal or Conversion of Existing Development

Flood damages can be avoided by permanent evacuation of the floodplain through complete removal of structures or through the conversion of the structures to some less flood vulnerable use. The feasibility of removal or conversion depends on public support and upon the value of the structures in the flood prone areas and their effect upon the movement of floodwaters. Structures located in floodways designated in flood insurance studies are good possibilities for removal. A program of evacuation, removal or conversion can be implemented using: public acquisition, urban renewal, razing, nonconforming use provisions in zoning ordinances, public nuisance actions and conversion of use.

Public Acquisition

The most positive way in which evacuation, removal or conversion of floodprone areas can be achieved is through public purchase. This can be accomplished through negotiation, condemnation, dedication, and donation. The acquired floodplain may be sold or leased by imposing restrictions on its development for uses which are flood-vulnerable. Acquisition is most appropriate in or near urban areas where open space or park lands are desired by the community.

Easement acquisition has been widely suggested but rarely applied. In most applications acquisition is almost always in fee. Easements are considered to be too complicated and offer limited benefits. Theoretically, easements offer many of the protective advantages of acquiring full title, but at lower costs. Certain productive uses may be continued such as agriculture. Despite the apparent advantages of easements, actual experience of other agencies has been disappointing. Costs have been high - often approaching 50 to 90 percent of full market value - with far fewer long-term benefits than fee purchase. Extensive public use of lands is usually not acceptable under an easement.

An acquisition program might be selectively applied to floodway areas, erosion or mudslide areas. The total number of acquired properties would be restricted if acquisition were focused upon the most serious hazard areas.

Floodways are delineated along rivers and streams for passage of flood flows and are usually of limited width. They are linear strips of land suitable for use as parks and parkways as well as for passage of flood flows. Damage to existing structures may be great in these areas due to extreme flood heights, velocities, and frequencies of inundation. In addition, structures and fills block flood flows, increasing flood heights on other lands. FIA regulations prohibit fills and structures in these areas. Consequently, existing structures are nonconforming.

Acquisition of floodprone areas may be cost effective when considering the total cost of flood hazard mitigation, recreation, pollution control, etc.

Acquisition is a permanent solution to the flood problem in that it prevents land uses from occurring in the floodplain if those land uses will result in heavy flood damages. Acquisition may also minimize maintenance needs for flood contol. Finally acquisition of fee provides public access which allows use of the acquired area as open space.

Community programs which may benefit from floodplain acquisition include:

1. open space and recreation,
2. urban renewal and redevelopment,
3. protection of prime agricultural lands,
4. protection of critical habitats, and
5. effects to reduce pollution.

In most areas acquisition is very costly and usually is not feasible for economic reasons. In addition, there may be resistance from landowners whose land would be acquired. Finally landowners adjacent to the acquired land may be concerned about the effect of the public access to areas bordering their land, if the acquired land is used for recreation.

In conclusion, acquisition is always considered even though the cost is usually high. The benefits associated with acquisition should include recreation, open space preservation, etc. and there is the possibility of funding acquistion costs with local, state or federal agencies. Acquisition will be identified as a feasible ELEMENT when the cost is comparable with the cost of channel modifications or when there is a potential multipurpose use.

Urban Renewal

Public or private redevelopment of floodprone areas can be achieved by the purchase of land that has deteriorated; the land is then cleared and redeveloped for less floodprone use. This is a form of acquisition in which land with lower value may be purchased and upgraded as part of a larger project.

In addition to the general advantages of acquisition, urban renewal may be eligible for federal funding programs. These sources of funding are discussed in Chapter 8.

One disadvantage of urban renewal is that using federal money often mires a problem solution in large amounts of red tape. This method also is limited to locations where other agencies are doing or contemplating urban renewal projects. In the Waterways Planning Study computer program urban renewal is not identified as a possible flood damage reduction 'ELEMENT'. Instead, it is included in the evaluation of funding sources.

Razing

Buildings on lands subject to periodic flood damage often go unrepaired and continue deteriorating with each major storm. State laws or local ordinances can be passed granting local jurisdictions the power to raze and remove such buildings or order these removals. Razing might be most feasible after a flood when the Federal Insurance Administration might pay for the removal and for relocating the residents.

Razing removes endangered, damaged structures which present a safety hazard. It removes an object that might be a source of culvert-clogging debris in future storms. Further, once the structure is removed, the District could encourage regulation of land use to prevent new building in that area. Razing has the advantage of being relatively inexpensive to the public agency since the landowner normally bears the cost of the razing.

A disadvantage of razing is that it may take sometime to find the land owner and force him to raze a damaged building. Furthermore, the land remains in private ownership and there is a continuing possibility that, without zoning changes, some new troublesome use could appear on the land at a later date.

Razing is an acceptable short term solution to an immediate problem. It is most effective in combination with a regulatory floodplain management program. Razing is selected where flooding is estimated to be very frequent and damages are low.

Nonconforming Uses

The adoption of a proper zoning ordinance and the application of zoning districts and floodland regulations may make some existing uses nonconforming. Nonconforming uses are those uses in existence at the time of the adoption of a zoning ordinance that do not conform to the use restrictions of the ordinance. For example, if a zoning ordinance prohibits residential uses on floodlands, existing residences in the floodland would become nonconforming uses. Nonconforming uses are limited in the type of expansion and upgrading that is allowed unless permanently changed to a conforming use. Use of this tool is necessary to prevent the increase in the floodplain of uses that are subject to flood damage.

The main advantage is that this ELEMENT is very inexpensive. Eventually, most of the land uses may become conforming and less prone to flood damage because at some point the necessary changes will be made as part of desired structural changes.

However, use of nonconforming zoning really does not solve the problem. In fact it also may cause the character of the area with nonconforming uses to deteriorate because property owners, believing they are restricted in the use of their property, may limit the upkeep on it. Nonconforming use zoning is usually not the best solution but it may be used to prevent the degree of flood hazard from becoming worse.

Public Nuisance

The deposition of materials and the construction or placement of structures within creek banks may constrict the channel flow, causing higher flood stages and increase in the upstream floodplain area and corresponding increase in flood damages.

Ordinances can be prepared to declare that every structure, building, fill or development placed within any watercourse or adjacent floodplain is a public nuisance and may be enjoined or abated by action of appropriate jurisdiction.

For example, the District's existing Ordinance 74-1 prohibits:

1. Pollution of water supplies of the District.

2. Construction, grading, excavation, deposition of material, construction of any discharge outlet or planting of flora within a designated floodway, upon or within the banks of a watercourse or District project or trespass on District property without having first secured a permit or written approval from the District.

Section 8-8 specifies that the provisions of the Ordinance are enforceable "by every civil and penal means available to the District" against direct violation of provisions or against failure to satisfy terms of a permit. "As an additional remedy, and if essential to the health, welfare or safety of the general public, the Board may order the work to be done, excavation replaced, material removed, or may order any construction or structures placed contrary to the terms of the Ordinance removed which work must be paid for by the violator."

This ELEMENT is necessary to protect identified floodways from being encroached upon by surrounding property owners. It also allows the District to insure that impediments to flow can be removed quickly. However, abatement of public nuisance will not solve existing problems. Its use is limited to keeping existing solutions to flood problems from being reduced in effectiveness. Therefore, public nuisance ordinances are not identified as possible alternatives in the waterways planning study screening analysis

Inducing Conversion of Use

In some flood-prone areas it may be possible to induce property owners to voluntarily convert the existing land use to one which is less vulnerable to flood damages. Achieving this goal will require some education of the property owner. Thus, the District must develop information to emphasize the full costs of flood damage and to show that the property owner will suffer little long term economic damage by the conversion.

Conversion of use is a good solution to the problem of potential damages because it requires no channel modification. Since the change is voluntary it will probably persist, unless the ownership of property changes.

Inducing conversion of use usually requires significant staff time devoted to each property owner. In a large urban area, the cost of this effort may be large. Also, the free market tends to result in most property being used in the most economical fashion consistent with the law. Therefore, most attempts to induce changes in use may not be successful because they may require the homeowner to act against his economic self interest.

Because of the time involved, efforts to induce conversion of use should be directed at property owners who would suffer extensive damages. Thus the return for the staff time invested in terms of damages avoided because of conversion of use could be maximized. Information on potential damages and benefits of conversion could be developed in detail and distributed to those for whom conversion of use is feasible.

Public Works Programs

Existing public facilities such as roads, bridges, utilities, and community buildings are periodically reconstructed for reasons of functional or structural obsolescence. The reconstruction presents an opportunity to reduce the risk of flood damage by elevating roads and utilities above flood levels, incorporating floodproofing measures into the design, or relocating the facility. Generally the District shares the cost of replacing the facility with the public agency within whose jurisdiction the facility is located. The District can either wait for the public agency to replace or upgrade the facility or plan a change in the facility for flood control purposes and approach the public agency that has jurisdiction about replacing the structure when the District plans to increase the flow capacity of the structure. The financing and implementation of this ELEMENT are discussed in the FUNDING Chapter under Capital Improvement Programs.

Replacing a structure and upgrading its capacity to carry flood flows is an efficient use of tax dollars. It also limits disruption of the surrounding area in solving a flooding problem.

Timing of cooperative projects may be a problem. In some cases the District may have to wait a long time to remedy a flood problem if the District intends to wait for a local jurisdiction to decide to upgrade a facility.

The District should seek to coordinate planning and construction with local jurisdictions whenever a flood control project includes alteration of a structure under the jurisdiction of another public agency. Good candidates are culverts and bridges.

In the decision matrix program public works programs are not identified as possible flood damage reduction 'ELEMENTS'. They are, instead, included in the evaluation of "funding sources".

Discouragement of Development

Future flood damages can be avoided by discouraging development in flood-prone areas. There are several ways in which this can be accomplished, including educational programs, warning signs, recordation, tax assessment practices, financing policies, and public development programs. "Discouragement of Development" is a possible solution ELEMENT where the flooded area is presently undeveloped.

Education

The use of educational programs to bring flood information to the attention of the public is based on the assumption that responsible citizens would be reluctant to risk property losses.

Warning Signs

Warning signs may be used to delineate flood hazard areas. Such signs should be located in areas where they can be readily seen by potential buyers and developers. The sign should indicate the source of flooding, the estimated frequency of flooding and approximate flood depth.

Recordation

Flood hazard maps could be filed with the County Recorder Office. This type of recording would result in the abstract of the title of each property affected containing an entry referencing the flood hazard. Subsequent conveyances and title searches would therefore also mention the flood hazard, alerting both the land purchaser and the assessor to the danger.

Tax Assessment Practices

Some form of tax relief could be provided to owners of lands subject to flooding in order to encourage less flood-vulnerable use. The assessment of lands retained in open space use by private owners in conformance with adopted land use plans would otherwise reflect this fact and provide a value and rate to compensate for the profit that could be realized through conversion to more flood-vulnerable uses. At the same time, floodlands that are developed contrary to the adopted plan could be assessed at a value and taxed at a rate high enough to recover the public burden of protecting such development.

Financing Policies

Almost all building or construction today involves loans or mortgages by private lenders, many of whom are insured by the Federal Housing Administration, Farmers Home Administration, or Veterans Administration. Knowledge on the part of these private lenders and federal agencies of the flood hazards involved and their adoption of policies denying loans or loan insurance for construction on floodlands would significantly discourage floodland development.

Public Development Policies

The availability of utilities and other community facilities in floodland areas serves to attract subdividers, developers, and home purchasers. Of great importance to the discouragement of such development is the adoption of, and adherence to, public development policies covering the extension of public utilities, such as water supply and sanitary sewer system, and the construction of community facilities, such as schools and streets in floodprone areas. Such action must be taken well in advance of development pressures.

Regulation of Uses in Floodplain

Remedial flood damage reduction measures are costly and difficult to implement. Regulation of flood-prone uses is the most efficient and economical method of preventing flood damage.

Devices for prohibiting or regulating floodplain development include selection and application of zoning districts that are compatible with the flood hazards involved and the adoption of appropriate zoning, subdivision, sanitary, and building ordinances.

Resolution No. 79-77 establishes the District's policy of encouraging the local governments to use floodplain management techniques such as floodplain zoning ordinances, flood warning systems, and meeting applicable requirements of the National Flood Insurance Program.

Flood Insurance Program - Flood Management Phase

The flood management phase of the National Flood Insurance Program is broad based and incorporates many of the guidelines found in individual elements of a flood damage reduction program. Communities do not have the option of ignoring the Federal program requirements. The 1968 National Flood Insurance Act stipulated that flood insurance shall not be sold within a community unless the community has adopted adequate floodplain management regulations. The floodplain management and construction requirements are very useful in limiting the intensification of potential damages as property in the County develops. The program has also helped clarify potential damages and educate people in the County about existing flood hazards.

The purpose of this phase of the Flood Insurance Program is to prevent development in floodplains that will increase the amount of damage that would be caused by a 100-year flood.

The main advantage of this program is that the local jurisdictions are forced to require flood mitigation measures in new land developments. Floodplain management options are identified in the Waterways Planning Study where the flooded area is not completely developed.

Floodplain Zoning

Floodplain zoning ordinances regulate and restrict in the public interest the uses which can be made of property in flood prone areas. The ordinances consist of two parts: (1) a text of specific regulations applying to the zone; and (2) a map delineating the zone boundaries, the floodplain and floodway. A floodplain is defined as an area susceptible to some level of inundation caused by a certain magnitude of flood flow; for example, the 100-year floodplain is the area which would be inundated by the flood having a one percent chance of being equalled or exceeded in any given year. A floodway consists of a river or watercourse channel and the adjacent land area that must be reserved in order to discharge the base flood (1 percent flood) without cumulatively increasing the water surface elevation more than a designated height. Establishing these encroachment lines on either side of a watercourse provides a legal basis for the maintenance of open space uses within the floodway.

Currently, cities within Santa Clara County regulate floodprone areas at least to the minimum extent required for participation in the National Flood Insurance Program. These FIA regulations are adequate for some areas such that floodplain zoning may not be required. However, zoning can be used:

1. to control land development and use where FIA did not specify a floodway or where a creek was studied by approximate methods,

2. to provide comprehensive control which includes those floodprone areas not designated by FIA (where base flood average depth is less than one-foot, for example), in which damages still may occur, and in which land development and use still may have an impact on the extent of future flooding,

3. to provide for more specific or restrictive land use and development criteria than those specified in the minimum FIA regulations, and

4. to notify potential land buyers of the flood hazard.

Zoning is implemented through individual cities and counties.

All cities and the County have, as a minimum, floodplain zoning regulations required by the Federal Flood Insurance Act. Therefore, the District can identify areas where additional zoning regulations might be appropriate and suggest that zoning agencies use FIA maps and regulations as a basis to develop more comprehensive zoning ordinances. The District can perform the detailed hydraulic analyses necessary to establish the ordinances. The District can suggest floodplain zoning of appropriate areas in combination with or as an alternative to other damage reduction measures.

Subdivision Ordinances

Subdivision ordinances may be used to prohibit the subdivision of lands not suited to the uses intended by a developer and to require the proper improvement of streets, building sites and flood protection measures prior to dedication and sale.

Subdivision ordinances could be designed to:

1. Prohibit the creation of building sites on lands subject to the 100-year flood.

2. Require the designation of floodprone areas on all maps.

3. Require the design and construction of all public and private roads, bridges, and other facilities so as to withstand flood velocities, prevent isolation, utility outages, and disruption of transportation and so as not to obstruct floodwaters, increase flood flow velocities or flood stage height, or retard the movement of floodwaters.

4. Require dedication of floodways necessary to adequately provide for containment of the 100-year flood flow.

Sanitary Ordinances

Sanitary ordinances can be effectively used to eliminate the health problems which could result from floodwaters disrupting private sewage disposal systems or water supply systems. A sanitary ordinance should be designed to:

1. Require a sanitary permit prior to the installation of any system or to the construction or modification of any building, with the application for such permit showing the floodplain boundaries.

2. Prohibit on-site soil absorption sewage disposal systems and private disposal water supply systems in flood hazard areas.

3. Require the replacement of existing on-site sewage disposal systems lying in floodlands with alternate systems, such as public sanitary sewerage or holding tanks.

Building Ordinances

Building ordinances can be effectively used to ensure that structures, such as buildings, bridges and roads, are protected from flood damage. The design and construction of structures in the floodplain can best be regulated by ordinances designed to:

1. Require foundation, base supports, footings, and other anchorage to withstand floodflow velocities and hydrostatic pressures; and require the use of materials that will not deteriorate or otherwise be damaged under submerged conditions.

2. Require all floors and flood-vulnerable utilities to be at an elevation of at least two feet above the level of the 100-year flood. In addition, the ground level surrounding any building shall be raised to an elevation of no less than one foot above the level of the 100-year flood for a horizontal distance of at least 15 feet from the building walls.

3. Require appropriate floodproofing measures, including structural modifications and installation of special equipment.

4. Require bridge and culvert openings to have adequate openings to pass high-flood flows and all structures to be designed to maximize the passage of debris.

Erosion/Sedimentation Control Program

High flows can erode the channel banks. Sediment can reduce channel capacity and damage structures. Controlling erosion and sedimentation involves both corrective and preventive measures. Corrective measures usually involve structural alternatives and preventive measures usually involve non-structural alternatives.

Structural Measures

Channel Lining

Channel lining is a corrective measure that is used where erosion is a major ongoing problem. Channel lining usually would be required where flow velocities exceed the velocity that causes erosion. Erosion repair involves restoring the desired shape of the channel and then covering the restored channel with a layer of concrete, gabions or rock for protection.

Where erosion is a major problem all or most of the vegetation or habitat will have eroded away; therefore, the impact on the stream environment of lining the channel is usually minimal. However, channel lining may still have a large impact on groundwater recharge from the channel.

Advantages of channel lining include the following:

1. Lining will solve erosion problems.

2. Lining may reduce the roughness of the channel so that the portion of the channel can carry more flow reducing the average annual flood damages for that area.

3. Lining may also reduce maintenance costs for the reach.

Disadvantages of channel lining include the following:

1. Lining a channel with concrete may reduce groundwater recharge and require off-stream mitigation.

2. Channel lining, especially with concrete, can be expensive.

Channel lining is included as a part of any flood control work where severe erosion has been observed or is anticipated based on analysis of soils and flow velocity.

Bank Repair

This ELEMENT is a corrective measure which involves installation of limited amounts of concrete lining, gabions, sacked concrete or rock riprap only where localized erosion is occurring and causing a problem. It is intended only to remedy local problems and protect local structures; it is not intended to and does not increase channel capacity.

Often this remedy is used where normal channel velocity would not be erosive but erosion occurs at places where the channel unusual flow conditions occur such as bends or brief constrictions. Bank repair is an ELEMENT of the Maintenance Program.

Drop Structures

Drop structures are used to flatten the channel gradient and reduce the velocity of the flow through a reach to a point where erosion will not occur. A drop structure is made of concrete or gabions and is composed of two parts: a relatively vertical face down which the water falls as it moves through the desired change in elevation and a stilling basin immediately downstream which reduces the flow velocity to a non-erosive level.

Drop structures should be considered as an alternative to lining a steep eroding channel, especially where there is groundwater recharge.

Sediment Basins

Sediment basins are designed to allow the rocks, sand, gravel and silt suspended in floodwaters to be deposited in the channel. Ideally, a sediment basin should be large enough to hold the sediment generated by one winter's storms (possibly the same as that generated by the 100-year storm).

If the sediment is deposited in the sediment basin then the District benefits in at least three ways.

1. Maintenance costs are reduced because all sediment is removed from one location which is designed in part to make sediment removal easy.

2. Downstream structures last longer because they are not subject to the erosive action of fast flowing water containing sand and gravel.

3. Flooding is reduced because the amount of sediment that would settle otherwise in the channel (reducing its capacity) is reduced.

However, sediment basins can be very large and costly. Furthermore, if a basin becomes full before the end of the rainy season and is not cleared before the following storms, it loses its effectiveness completely.

Non-Structural Measures

Non-structural measures are forms of land use control which are instituted to prevent or solve sedimentation or erosion problems.

Public Acquisition

Public acquistion of land can have several goals. One is to prevent development on land where soil conditions are such that development would initiate an ongoing sediment generation problem. A second goal could be to purchase a site where sediment generation already is a problem so that actions can be taken to solve the existing problem. This second goal allows a problem to be solved at its source rather than at many downstream sites. Examples of a site that would be purchased to achieve this second goal are the quarry sites on Calabazas Creek that are sources of substantial amounts of sediment. A third goal could be to purchase land along creeks where local erosion is a problem.

It may be less expensive to acquire land to prevent or remedy sediment generation problems rather than to install and operate a sediment basin. Land acquistion can preserve open space for parks and other beneficial public uses. However, Land acquisition is costly. If the land acquired is already a problem site, rehabilitation will add substantially to the cost.

Land acquisition should be considered if a portion of a watershed is a source of large amounts of sediment given the area of the watershed. Therefore, the unit production of sediment, in terms of cubic yards/acre of watershed, needs to be calculated to determine which problems may be most suitably solved by this ELEMENT.

Land Treatment

One form of land treatment prevents sediment generation from a watershed by reducing amounts and velocity of runoff, thus reducing erosion in the watershed. Another form of land treatment includes measures to rehabilitate a damaged, eroding watershed.

These measures can be taken on land under public or private ownership. Private owners can benefit from land treatment because it conserves the value and productivity of their land.

Regulation

Regulation involves the adoption, by public agencies with jurisdiction, of land use ordinances which limit the uses to which the land can be put. Regulation can take three forms:

- Zoning which limits the type of land use permitted in an area. Zoning can prevent land uses which are likely to result in sediment generation.
- Grading Ordinances which control the timing of construction projects and practices used in construction. Grading and movement of heavy machinery

can disturb the soil and make on site erosion and sediment production more likely.

- Permits which control activities of land owners on a case by case basis to insure that those activities do not result in sediment generation from the site.

These land use controls limit the actions of property owners at little cost to the District and therefore are economically very beneficial options.

However, they are imposed not by the District but by other agencies. Those agencies, for which stream management is not a primary function, may grant exceptions to these regulations, reducing the effectiveness of these measures.

Stream Environment Program

The District is responsible for maintaining and enhancing the quality of the environment in the floodplain. The District has accepted this responsibility where possible because, as a public agency, the District tries to respond to the expressed will of the electorate as much as possible while pursuing the District's statutory responsibilities. The District takes both corrective and preventive measures to maximize the quality of the stream environment.

Corrective Measures

Corrective measures are intended to remedy problems that already exist. Sometimes corrective measures in one area are used as mitigation for the impacts of construction by the District of a flood control project in another area.

Pollution Control

There are many sources of "pollution" that enter streams. The District does not have any control over most of these; if District employees observe pollutants entering a stream they report their observations to the Regional Board or the Health Department, agencies empowered to require the polluter to cease and abate the pollution. The District's maintenance program removes trash that has been deposited in creeks or debris and vegetation that has been swept down the creek by flood flows. Removal of this sort of material is accomplished during normal maintenance operations. However, since the employees of the District are constantly monitoring the conditions in the creeks, those employees are also alert for situations that cause pollution of the creeks. If pollution is noted, the District notifies the agencies legally empowered to take action to stop and clean up the pollution; these agencies are the Regional Water Quality Control Boards and the Health Department.

If attempts are being made by other agencies to clean up pollutants, the District can cooperate with them and help in the clean up effort. The District can lend equipment and temporarily alter operations to coordinate with the clean up process. An advantage of pollution control is that environmental and habitat values in the channel are protected. However, a disadvantage is that clean up efforts are costly, especially if they are labor intensive. The District performs clean up actions as part of its normal maintenance activities.

Revegetation

Often flooding, erosion or construction of flood control works results in extensive damage to or elimination of vegetation on creek banks and land adjacent to the creek. When this occurs the District can plant and encourage the growth of vegetation. This includes irrigating the new planting and mulching the soil to prevent erosion and weed growth.

The types of plants used in revegetation should:

1. Be particularly resistant to erosion;
2. Provide habitat for a desired species of animal or a desired ecosystem;
3. Satisfy the desires of local residents;
4. Require low maintenance and little water.

In some cases, revegetation may be the only feasible or acceptable mitigation measure.

An advantage of revegetation is that it can restore or enhance the environmental setting of a creek. Revegetation, especially in park areas, can improve the quality of life for nearby residents. The District also receives public relations benefits from revegetation projects. Revegetation reduces erosion of channel banks caused both by local runoff flowing toward the creek over the banks and by instream flow. Reducing erosion minimizes maintenance costs and may eliminate the need for a large capital project to repair damages.

A disadvantage to this ELEMENT is that seeds and plants, especially those in larger containers, are expensive. Furthermore, several years of continuous maintenance are required before the vegetation becomes established enough to withstand dry summers without irrigation. An area that is revegetated may require permanent irrigation, which adds to both the initial and the ongoing costs. There is always some risk that revegetation may be lost due to extreme weather conditions or irrigation system failure. Vegetation and irrigation systems are also subject to vandalism which can result in an additional expense. Revegetation is considered where existing vegetation is sparse or habitat quality is low.

Fishery Enhancement

Many streams in the County have historically contained fish and were spawning areas for anadramous fish. Urbanization has had a significant adverse impact on these fisheries.

Depending on their design, flood control projects can either reduce or improve the conditions that favor the fishery in the stream. Features can be incorporated that benefit the fishery. For example, low flow channels provide adequate water depths for fish to live and swim, and fish ladders in drop structures enable fish to migrate upstream past the drop structures. Without the ladder, a drop structure can be an absolute barrier to further upstream migration. Also, limited debris removal from channels can ensure that enough water remains to form pools in which fish can live.

Enhancing the fisheries in the county improves the quality of life for residents in this area and increases the potential for maintaining the diversity in the ecology. However, in some cases adding fishery features to a flood control project increases design time, project costs and maintenance costs.

During the environmental review process the California Department of Fish and Game evaluates the effect of flood control projects on the fishery in a stream. District staff discusses fishery enhancement issues with the Department of Fish and Game during design and accommodates their recommendations, where possible, in the final design on most flood control projects.

Preventive Measures

Preventive measures are taken to preserve valuable environmental habitat. Such measures take one of two forms: public regulation of private use and public acquisition.

Regulation

Regulation in a stream environment program would limit land uses in order to protect environmental conditions on the land or on adjacent land. Examples of forms of regulation include:

- Zoning such as zoning an area as open space
- Permits that allow one time activities but require that actions be taken to safeguard environmental conditions, the requirements are set on a case-by-case basis.
- Ordinances are limitations on certain actions that are applicable to the general population.

In almost all cases these regulations are instituted by other public agencies. The District can suggest conditions to protect the environment during the permit review process but it cannot enforce these requirements.

Public Acquisition

Public acquisition of land for protection of the stream environment ensures that the uses for the land are compatible with the environmental values to be protected. Generally land is purchased to protect the environmental condition and can also provide recreational opportunities and preserve open space.

The District can purchase land for stream environmental protection as part of its flood control activities for example, for mitigation requirements. Often the District can share the cost of purchase of the land with other interested agencies.

Maintenance Program

The District is responsible for maintaining both constructed and unmodified facilities where the District has the necessary right of way. As with erosion, flood control and stream environment programs, maintenance activities consist of both corrective and preventat measures.

Corrective Measures

Routine Maintenance

Routine maintenance consists of selective channel clearing, debris and sediment removal, weed and rodent control and minor erosion repair work. Chapter 6 of this report examines in detail how routine maintenance, especially channel cleaning and sediment removal, affects the hydraulic capacity of channels and thus, the flood damage reduction program.

Routine maintenance requirements are an important consideration in the planning of flood control works. Where multi-purpose recreational usage is anticipated the maintenance responsibility is transferred to the recreation agency, in accordance with the District's joint use policy.

Remedial Maintenance

Remedial maintenance activities consist of major erosion repair projects and facility rehabilitation projects. Often these projects are eligible for alternative funding if the erosion or facility damage occurred due to a large storm. Several of these FUNDING sources are described in Chapter 8 of this report.

Preventive Measures

Preventive measures include public acquisition and regulation of floodplain uses. These ELEMENTS are intended to reduce or eliminate the need for or cost of maintenance. Public acquisition of floodplains would allow the creek to remain natural thus reducing maintenance needs. Ordinances regulating streamside development can ensure that maintenance of streams is not hindered or made expensive. Ordinance administration ensures adequate access and ease of maintenance.